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Report of the President

By EARL I. SPONABLE

Movietonews, Inc., New York, N.Y.

It is customary at this time for the President of the Society to submit his annual report, and to bring to your attention such matters as seem to him worthy of your consideration. First, I am glad to be able to report to you that the year 1949 has been filled with healthy activity on the part of the Society and has resulted in an even greater service to the motion picture industry than at any time in the past.

The total membership at this time is over 3000: a real credit to the Membership Committee which has brought in 280 new members since April 1 of this year. This number of new members has more than made up for an unusually high loss of previous members, due probably to the aftermath of the war and to changing business conditions. Among our membership are representatives from 48 foreign countries, including Canada and Mexico, and from each of our 48 states.

I am proud of the work done by our 38 standing committees in which 471 members are giving their time to help improve the industry through standardization, and in other important ways. Parenthetically, at this point I would like to say that we would welcome the assistance of any members who are not now serving on committees, and who would like to do so. I suggest they get in touch with the chairman of the committee in which they are interested.

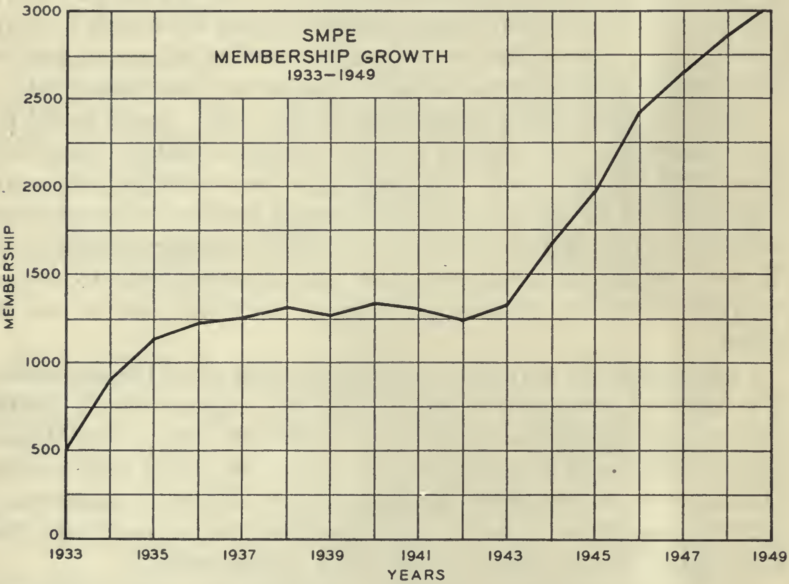
The Officers and Governors have been diligent in their jobs and most patient and helpful to me at Board Meetings. I want particularly to thank those men who are now finishing their terms of office and to urge them not to diminish their activity in Society affairs.

The general office is now well established at 342 Madison Avenue in New York City. The space, while not elaborate, has been adequate for our present needs. By the way of review, we have an efficient, small staff headed by Boyce Nemec, our Executive Secretary. The work of the engineering committees is handled by William H. Deacy, Jr., Staff Engineer; and Sigmund Muskat is the Office Manager.

Presented: October 10, 1949, at the SMPE Convention in Hollywood.

Improvement has been made in various office activities: The accounting system has been modernized; the committee work is being handled rapidly and efficiently; membership applications are being processed promptly; Journal publication has been speeded up; and our press relations are much improved.

Besides its own committee work, the Society now contributes to the support of, and has representation in, related organizations including the American Standards Association, the Inter-Society Color



Council, the United States National Committee of the International Commission on Illumination, the American Documentation Institute, and the National Fire Protection Association.

Our three local Sections have been unusually active during the current year. The chairmen and managers have arranged for papers that have commanded increased attendance. One highlight of the year was the joint meeting of the New York and Chicago Sections through the use of inter-city television, dealing with "A Study of Television Lighting." The combined attendance at this one meeting exceeded 1000 and resulted in important publicity and improved public relations for the Society.

The 65th Semiannual Convention, held this past spring in New York City, was an outstanding success. Its theme of television attracted an all-time record registration of 715. This current Convention, the Society's 66th, also has a program of great interest that has been made possible by most diligent work on the part of the Program and Local Arrangements Committees. I am sure that this Hollywood Convention will be one that we all shall remember as an enlightening experience.

Printing costs have gone up along with everything else. This has led to a study of the format of the JOURNAL, and designing it to use the available space more efficiently. Careful planning is in progress in co-operation with the Society's printer to effect a transition to a somewhat new dress wherein we may use for the most part a two-column page and achieve better readability and more text material per page, at practically no increase in cost.

During the year the Society published a book on theater engineering entitled *The Motion Picture Theater*, with which I believe most of you are familiar. In spite of a carefully worked out plan for sales we have not received the number of orders we anticipated. I believe, however, that an important reference book such as this will be in demand for some time to come. Our other less ambitious publications in the form of monographs entitled "Films in Television," "Theater Television," "High-Speed Photography," and "Color Symposium" were well received, have paid their costs, and have helped to gain the Society recognition in their respective fields.

The Society has continued its service of making and supplying test films. New films this year include a 16-mm sound service test film, and a television visual test film. Both of these films are very much needed in the industry. They will be described and samples will be shown at this meeting.

A number of new standards have been approved during the current year, and have been published in the JOURNAL. Also, the Board of Governors has authorized the publication from time to time of special reports to be known as "SMPE Recommendations." While these Recommendations have not reached the stage of standards, they will have been approved by engineering committees and the Engineering Vice-President and should be a useful guide to equipment manufacturers. They will be printed to fit the standards cover, but colored paper will be used to distinguish them from adopted standards.

The financial position of the Society, while on a sound basis at present, requires careful watching. Our expenditures and receipts run about $125,000 per year. The year 1948 ended with a deficit of $8,724. This was partly due to non-repetitive expenses such as furniture for new offices. This year the indications are that we will nearly break even. Our net quick assets are over $90,000. Largely through the efforts of Don Hyndman we have materially increased our income from sustaining members. In 1945, income from this source was $8,087, was brought up to $20,250 in 1946, and this year it will total over $24,000. If we are to continue to expand our service to the industry it is obvious that our income must keep in step. Every possible source of revenue will be studied carefully and every effort made to keep our operating costs as low as is consistent with our program of service.

Never in the history of this Society has it had the standing, or commanded the respect of the leaders in the motion picture industry, that it does today. This is no mere accident, but rather is the cumulative result of teamwork among all its members. The pioneer work in theater television, largely due to the efforts of Paul Larsen and a few others, is beginning to be recognized. The recent Society answer to the request of the Federal Communications Commission for advice regarding theater television (which will be reported on later at this meeting by Don Hyndman) is an example of what I mean. Likewise, the Theatre Owners of America and the Motion Picture Association have sought our advice in this same matter. We must carry on and justify the confidence that has been placed with us to do the proper engineering job and to give technical guidance, not only to the motion picture industry as it is now constituted, but also to the new, closely allied art of television.

This brings me to our plans for the future. Our Past President, Loren Ryder, has emphasized over and over that the scope of the Society activities includes all phases of pictorial rendition of action. With this I am in hearty accord. We are concerned with television whether we all like it or not. While television did not develop within the motion picture industry and while credit for its conception and growth belongs to the electronic and radio engineers, there is, nevertheless, a very large area of common interest in the two fields. The vast accumulation of knowledge of production problems, lighting, photography, sound recording, film handling, and projection technique are all parts of this common area; and this accumulated knowl-

edge of the membership of this Society represents such values to the growing television art that the television engineer will find himself able to acquire this information in only one of two ways: either by arduous, costly, personal experience, or alternatively, by becoming a member of this Society. We have, therefore, much incentive to offer to the television engineer to join with us; and on our side, there is much to be gained by this union, both from the point of view of society economics and from that of service to the industry. It is for these basic reasons that your Board, after due committee consideration, decided to recommend to the membership that the name of the Society be changed to "Society of Motion Picture and Television Engineers," and that the founders and developers of this new allied art be actively encouraged to take part with us in developing a larger and more effective service. It is my sincere personal belief that such a change will profit the Society and the industry, and I hope that with your enthusiastic support of the enlarged program which I have just outlined, time will prove the wisdom of this course.

Perception of Television Random Noise

By PIERRE MERTZ

Bell Telephone Laboratories, New York, N.Y.

Summary—The perception of random noise in television has been clarified by studying its analogy to graininess in photography. In a television image the individual random noise grains are assumed analogous to photographic grains. Effective random noise power is obtained by cumulating and weighting actual noise powers over the video frequencies with a weighting function diminishing from unity toward increasing frequencies. These check reasonably well with preliminary experiments. The paper includes an analysis of the effect of changing the tone rendering and contrast of the television image.

The accumulation of data for guidance on tolerances to be placed on random noise in circuits used for television transmission has developed a fairly large number of parameters that cannot be neglected if the interpretation of these data is to be useful.[1] Among these parameters are some which concern the phenomena involved in the perception of the noise by the viewer. There is presented herewith a discussion of some of these phenomena.

The treatment covers several of the parameters, but it cannot presume to solve completely the problem of tolerances. It constitutes merely a first order attack on the major quantities involved.

The discussion is divided into three parts: (1) factors involving the granular appearance of the random noise; (2) factors involving the perception of adjacent differences in luminance; and (3) factors involving the translation of signal voltages into image luminances.

1. Influence of Granular Appearance

Certain phenomena in the perception of random noise have been clarified by studying its analogy to the effect of graininess in a photographic image.

Long study of photographic graininess[2] indicates that the perception of graininess involves two parameters of the emulsion:

1. The extent of the density variations in the emulsion caused by the grains;
2. The average size of the individual grains.

Presented: October 14, 1949, at the SMPE Convention in Hollywood.

LIST OF SYMBOLS

a	= a constant
A	= a constant, in one case being the constant area of a microdensitometer aperture
b	= a constant, in one case being a characterization of the "key" of a picture
B	= luminance, average picture luminance over an area
B_A	= adaptation luminance (millilamberts)
B_B	= luminance of test field (millilamberts)
B_S	= maximum luminance in surround field (millilamberts)
$B(\theta, \varphi)$	= luminance of surround field over elementary solid angle $d\omega$
c	= a constant
D	= ratio of actual viewing distance to a picture, to four times picture height
f	= frequency
f_e	= effective frequency
f_0	= upper cutoff frequency of low pass filter
g	= quantity evaluating appearance of graininess
k	= proportionality constant
K	= a constant, in one case a constant speed of scanning beam
n	= a number, in one case used as exponent, in another, an average number of photographic grains per unit area
N	= number of television scanning lines in picture height
p, q	= constants
r	= response of eye to granular luminance deviations
s	= index of graininess in photographic emulsion
S	= sensation (evaluated in number of perceptible steps)
T	= time taken by scanning or reproducing beam in sweeping across assumed sampling area when $D = 1$
u	= number of television scanning lines in sampling area height
v	= average number of noise spots per segment of scanning line across sampling area
V	= signal voltage
W	= mean square of luminance deviations (or "power") of random "noise"
W_e	= effective square of luminance deviations (or "power") of random "noise"
W_1	= "power" at threshold for "flat noise"
W_2	= "power" at threshold for "up-tilted noise"
$W(f)$	= mean square of luminance deviations (or "power") of random "noise" in unit frequency band at frequency f
δB	= rms of luminance departures from average, in a portion of the picture area
Δb	= increment in luminance, measured in effective photographic density units
ΔB	= increment in luminance, measured in millilamberts
Δv	= increment in signal, measured in decibels
ΔV	= increment in signal, measured in volts
φ	= angle measured about line of sight to a test field
θ	= angle in radians between line of sight to an elementary spot $d\omega$ and line of sight to a test field
σ_1	= rms departure from average in microdensitometer density measurement (idealized aperture)
σ_2	= rms departure from average in microdensitometer density measurement (actual aperture)
$d\omega$	= elementary solid angle in steradians

The graininess of a photographic emulsion is measured by exploring an arbitrary path over a region of it having constant average density over the gross parts of the region. This is carried out with a microdensitometer having a sampling aperture which is small but of suffi-

cient area to include a number of grain clumps simultaneously. From the microdensitometer record there is determined the root mean square deviation of the density about the mean.

A highly schematic illustration of this process is shown in Fig. 1. The sampling aperture is shown in one position along the path. It is shown square rather than with the usual round form to simplify some later discussion.

The microdensitometer readings will vary according to the size of the aperture used. In Fig. 2 an illustrative trace of the density is

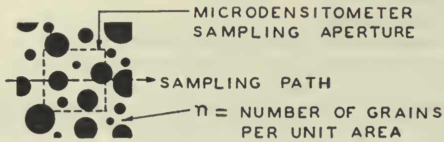


Fig. 1. Scheme of microdensitometer sampling.

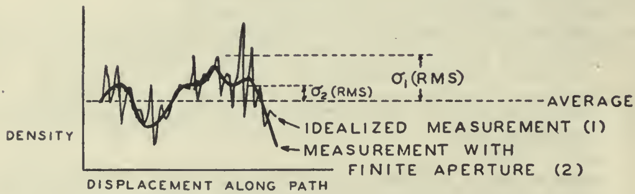


Fig. 2. Example of density readings.

compared with an idealized measurement made with an infinitesimal aperture. The ratio of the rms departures (σ_1 and σ_2) in density is approximately equal to the square root of the number of grains included in the aperture, thus

$$\sigma_1/\sigma_2 = \sqrt{nA} \tag{1}$$

where n = average number of grains per unit area;
A = area of effective aperture, measured on emulsion.

Hence in correlating measurements made with different apertures on the same emulsion, a constant quantity is the product of the rms density measurement by the square root of the aperture area. This is indicated as equal to the idealized rms density measurement divided by the square root of the number of grains per unit area.

$$s = \sigma_1/\sqrt{n} = \sigma_2 \sqrt{A} \tag{2}$$

This quantity is here called s, and used as an index of the graininess of the emulsion.

When the emulsion is viewed by the eye, a less definite but similar sampling aperture comes into play. This is caused by the limited resolving power of the eye, instead of the microdensitometer. The appearance of graininess, or evaluation by the eye of the quantity σ_2, is then equal to the quantity s divided by the square root of the sampling area. This new quantity is called g.

$$g = \sigma_2 = s/\sqrt{A} \tag{3}$$

The sampling area subtends a constant solid angle at the observer's eye as the viewing distance is changed. Thus at the greater viewing distances the area A on the emulsion increases, and the appearance of graininess is reduced.

In a television image the individual random noise grains are assumed as analogous to the photographic grains. The sampling area again subtends a constant solid angle at the observer's eye. The number of noise grains in this area is proportional to the product of the number of scanning lines in the area by the average number of grains in the portion of a scanning line included in the area. This last number can be computed if desired from a formula published by S. O. Rice[3] for the average number of zeros per second in random noise.

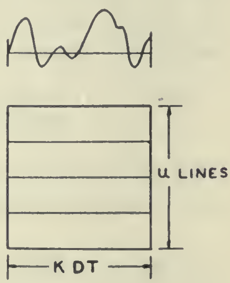


Fig. 3. Television sampling area.

It is found, however, that in television there is correlation between noise grains along a scanning line, according to the particular noise power distribution in the frequency spectrum. This is a fact which does not figure in the photographic analogy. In consequence the analogous appearance of graininess for the television must be computed in a slightly different manner.

A sampling area is illustrated in Fig. 3. A distribution of luminances along one scanning line is illustrated at the top. For small departures the deviation in luminance is nearly proportional to the negative of the deviation in density. The average response of a photocell over such a sampling interval of scanning line is known from scanning theory,[4] and is taken as analogous for the eye. Each Fourier component in the trace is attenuated by a weighting function characteristic of the sampling aperture or interval. In this case the sampling inter-

val will be assumed rectangular, of duration DT. D is a factor weighting viewing distance, which at four times picture height is taken equal to one, i.e.,

$$D = \frac{\text{viewing distance}}{4 \times \text{picture height}}.$$

T represents the time taken by the reproducing beam in sweeping across the sampling area when $D = 1$. The width of the sampling area on the picture screen is KDT, where K is the speed of the beam.

The "power" response, using this in the sense merely of the output of the photocell analogous to the eye, of a single scanning line trace, is given by

$$r^2 = \int_0^\infty W(f)\ [\sin \pi fDT/(\pi fDT)]^2\, df. \qquad (4)$$

The correlation which exists between noise grains along the scanning line in the sampling area drops to zero between scanning lines. Thus the square of the rms luminance deviation (or the "response power") averaged over the number u of scanning lines in the sampling area height is, as in the photographic case, the square of the rms deviation (or "response power") over one line divided by u or kDN.

Here N = number of scanning lines in picture height;
k = proportionality constant.

With all the constants adjusted to give 1 at $D = 1$, the effective noise power response is given by.

$$W_e = r^2/D = (1/D) \int^\infty W(f)\ [\sin \pi fDT/(\pi fDT)]^2\, df. \qquad (5)$$

Thus the effective random noise power is obtained by weighting and cumulating actual noise powers at the various video frequencies with a weighting function. This function diminishes from unity toward increasing frequencies approximately like the weighting function of a scanning aperture. Following this theory, then, one would expect threshold of perception to be obtained at a fixed effective random noise power for all distributions of the random noise.

The theory can be checked with some preliminary unpublished experimental data taken by M. W. Baldwin on the near threshold values of various distributions of television random noise, viewed at several distances. The twelve distributions experimented with are illustrated

in Fig. 4. "Flat" means a distribution which is substantially flat up to cutoff. "Up-tilted" means one in which rms amplitude in a narrow frequency band is proportional to the center frequency of that band up to the region of cutoff. "Coaxial" is a distribution which is expected in some hypothetical coaxial system designs. These noise distributions were viewed at distances $D = 0.625$, 1.0, and 2.0, respectively. The near threshold values of total measured random noise in each case as a function of upper cutoff frequency are indicated by the connected points in Fig. 5. The noise is measured in terms of the ratio of the rms of luminance departures δB, to the average luminance

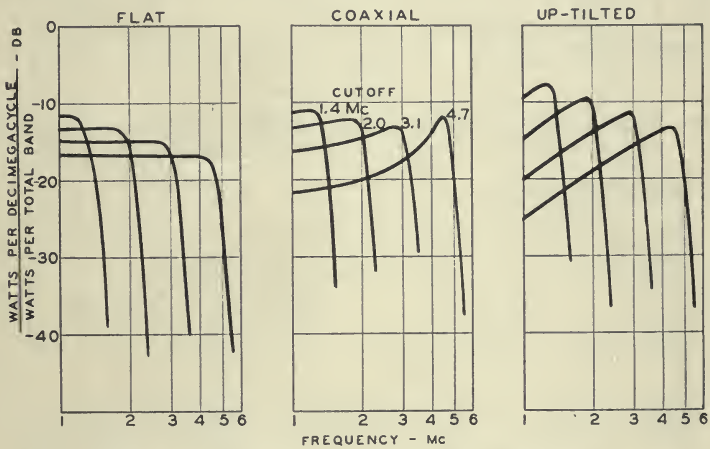


Fig. 4. Experimental random noise distributions.

$\overline{B}$. The logarithm of this is taken, as if db were used to represent an amplitude ratio. The quantity has sometimes been called "decilums."

In fitting equation (5) to these data it is necessary to choose a value for the sampling interval T. As will be indicated further below, this has been selected for the best fit at $T = 0.22$ microsecond. With this value the weighting functions for the three distances are shown by the curved lines in Fig. 6. The fit of the computation of equation (5) with experimental data under these conditions is shown by the curved lines in Fig. 5.

The fit is not perfect, but is considered reasonably good. The greatest discrepancies in trend seem to come at the shortest viewing distance. This suggests that the noise distributions which have been

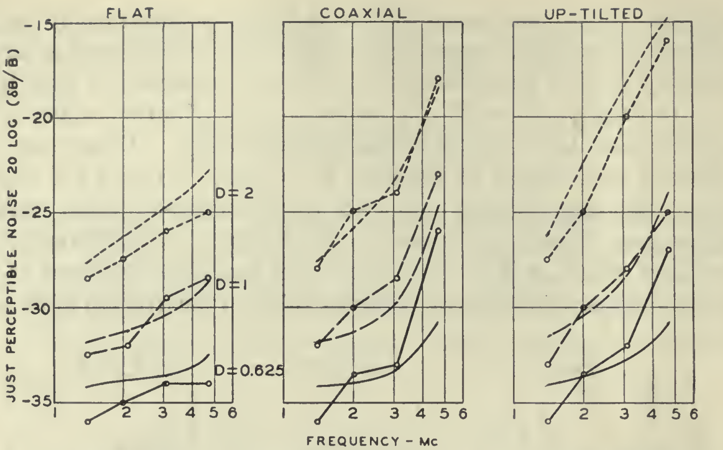


Fig. 5. Noise perception with distributions of Fig. 4; comparison with theory.

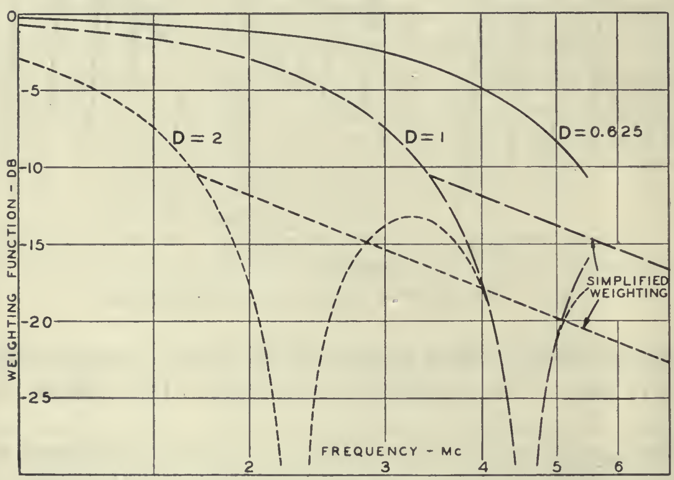


Fig. 6. Hypothetical visual weighting of noise.

shown in Fig. 4 are modified by the filtering effect of the picture tube electron beam spot before being viewed by the observer. The exact distribution of luminance in the spot is not known, but a computation of the filtering effect is shown in Fig. 7 on the assumption that the distribution follows a cosine squared law of such width as to come to zero weighting at 10 Mc.

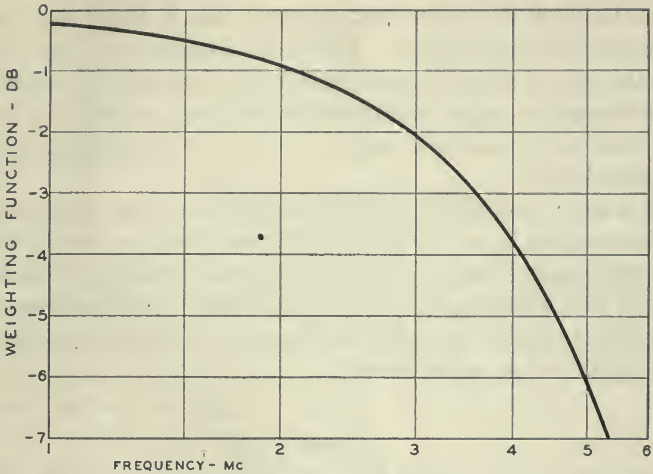


Fig. 7. Hypothetical filter effect of receiving cathode ray spot.

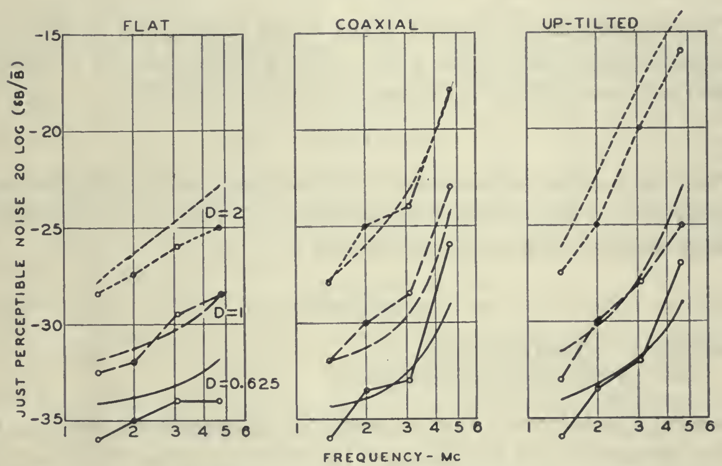


Fig. 8. Noise perception with distributions of Fig. 4; comparison with theory corrected by Fig. 7.

With this correction the experimental data are fitted as shown in Fig. 8. The fit is somewhat better than in Fig. 5, and the worst residual discrepancy is reduced to 3 db.

It would be expected that the law derived from analogy with photographic graininess should break down at very low frequencies because

the granularity in the horizontal direction then extends well beyond any reasonable sampling area. Such a breakdown has been found to exist in the case of narrow band distributions of noise well under 1 Mc. The low-frequency region and distributions under which the law appears invalid seem narrow enough not to be of too much consequence in its general use.

There is some interest in returning to the evaluation of the response from the sampling area of Fig. 3 and disregarding the correlation between noise grains along a scanning line. As noted above this can be done from Rice's treatment.[3] It can be assumed for the present purpose that the noise has an "effective frequency" f_e, which is defined as half the number of zeros per second.

Then

$$f_e^2 = \frac{\int^\infty f^2 W(f)\, df}{\int^\infty W(f)\, df}. \tag{6}$$

Thus the effective frequency is the radius of gyration of the power distribution figure about the y axis. The average number of spots of noise v per scanning line in the sampling area is equal to:

$$v = DTf_e\,. \tag{7}$$

Thus the total average number of noise grains in the sampling area is equal to uv. Hence following equation (1), but writing powers instead of density departures, and placing $na = uv$,

$$\begin{aligned} W_e &= W/(uv) \\ &= W/(kNTD^2f_e), \end{aligned} \tag{8}$$

where W_e = effective noise power;
W = actual total noise power.

Several simple laws can be immediately deduced from equation (8). As the distance factor D is changed the effective power W_e varies with the inverse square of the distance. Thus fixing W_e at a point corresponding to threshold gives a variation of W with the square of the distance, or an increase of 6 db with every doubling of the distance. This law is found to hold roughly with the data presented in Figs. 5 and 8. The simplicity of the law is lost in the more accurate formula of equation (5).

For the case of the flat noise distribution to an upper cutoff f_0, equation (6) becomes:

$$f_e = f_o/\sqrt{3}\,. \tag{9}$$

Also

$$W = f_o W(f)\,. \tag{10}$$

From equation (8),

$$\begin{aligned} W_e = cW/f_e &= cf_o W(f)(\sqrt{3}/f_o) \\ &= c\sqrt{3}W(f), \end{aligned} \tag{11}$$

where c = a constant, and the threshold of visibility of the noise is independent of the cutoff frequency f_o when the power per cycle, $W(f)$, is kept constant. This law appeared rather startling when first discovered experimentally by M. W. Baldwin in tests similar to those plotted in Figs. 5 and 8. It means that as noise is added by raising the cutoff frequency of a flat distribution, the masking effect of the additional fine grained noise exactly compensates for the increased noise amplitude, to keep the perception at a constant. The law is approximately followed by the data for the flat distribution in Figs. 5 and 8, where it would be represented by lines of 6 db per octave slope. The simplicity of the law is again lost in the formula of equation (5). The reality of the correlation which forms the basis for equation (5) is, however, shown by the data for the up-tilted distribution in Figs. 5 and 8. When the correlation is ignored, an equation similar to equation (11) is obtained, plotted with a slope of 6 db per octave in Figs. 5 and 8. The actual data, however, show a distinctly steeper slope, which is reasonably well indicated by equation (5).

Actually the differences between the data for the flat and up-tilted distributions can be used to give a sensitive evaluation of the sampling interval DT. If W_1 and W_2 are respectively the total powers at threshold for flat and up-tilted noise up to the same cutoff frequency, the ratio of these, from equations (6) and (8), is:

$$W_2/W_1 = 3/\sqrt{5} \qquad (1.3 \text{ db}). \tag{12}$$

From equation (5) the ratio is approximately:

$$W_2/W_1 \approx \pi^2 f_o DT/3. \tag{13}$$

A plot of the data, equation (12), and the best fit for equation (13), are shown in Fig. 9. The value of T is obtained from this best fit for example at the point where W_2/W_1 equals $\pi^2/3$ or 5.17 db. Here $T = 1/(f_oD) = 1/4.55 = 0.22$ microsecond. The plot of W_2/W_1 from

equation (5) without the simplifications of equation (13) is also shown in Fig. 9.

It seems doubtful that the sampling area should be so sharply defined in the eye as to give a weighting function with the deep minima shown by the curved lines in Fig. 6. Some exploration has accordingly been carried out of a weighting function which starts out at low frequencies with the curves of Fig. 6, but which before the minima are reached translates to straight lines as shown. The differences which

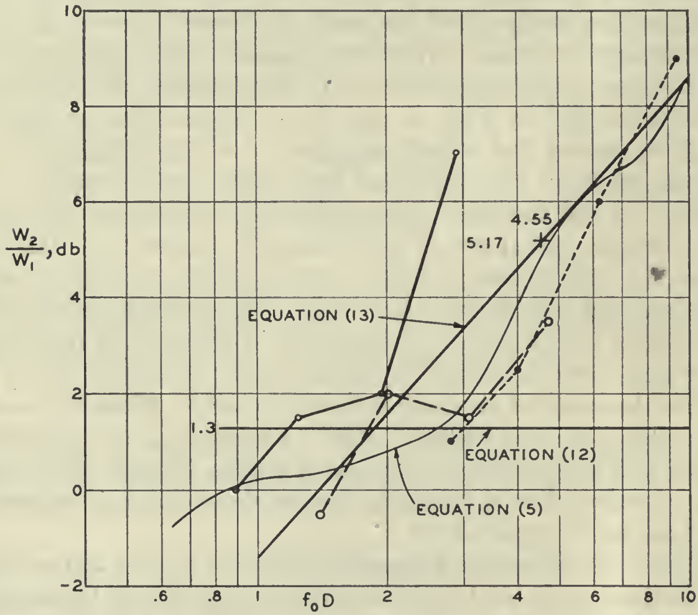


Fig. 9. Difference in perception between flat and up-tilted noise.

result from this in the particular comparisons of Figs. 5 and 8, are well under 1 db. The simpler form of weighting function appears practical, though later checks with narrower distributions of noise are desirable.

The value of DT which has been determined corresponds to 4.8 minutes of arc at the observer's eye. The sampling area is therefore larger, on a side, than the conventional one minute of arc of visual acuity. This is not unreasonable, inasmuch as the one minute figure is obtained with substantially 100 per cent contrast, while here the sampling area merges noise grains under near threshold conditions,

where the typical contrast is substantially less. It can be expected from this that the sampling area may vary in size from threshold conditions to random noise much above threshold. This is confirmed by the experimental viewing of fields of wide-band random noise. As the noise is reduced in amplitude to approach threshold, the characteristic granular form of the noise perceived at the higher intensities yields to larger floating nebulous masses.

2. PERCEPTION OF LUMINANCE DIFFERENCES

The threshold of perception of the difference in luminance between two adjacent areas is characterized, over a range, by a constant ratio of the difference in luminances to the greater of the two. This is known as the "Weber-Fechner law."[5] This threshold difference was further interpreted by Fechner as an elementary sensation step, thus

$$dS = dB/B. \tag{14}$$

The ratio on the right-hand side is known as the "Fechner fraction." The expression may be integrated, as

$$S = \log B + \text{constant}. \tag{15}$$

The range of validity of the Weber-Fechner law and the deviations from it outside this range have been the subject of much experiment. A general summary of some of this work has recently been presented by Moon and Spencer.[6]

This paper considers particularly two phases of the departures. The first is a gradual rise in the value of the threshold Fechner fraction toward lower luminances of the field. This is generally well known, and it is obvious that it must occur because at the threshold of perception the luminance perceived can just be distinguished from physical black, and the value of the Fechner fraction is therefore 1. Luminances just below this, hence, appear as "subjective black," and the threshold luminance gives the boundary of subjective black.

The second phase consists in the influence of glare light from a surrounding field. This is of great practical importance in daily vision and in the viewing of a picture, because the area being concentrated upon is almost never surrounded by substantial darkness. The treatment of this phase of the problem is much simplified by the "Holladay principle," which gives a weighting formula establishing the equivalence of any glare field distribution to a total field of constant luminance, which last is then called the "adaptation luminance."

This formula is:

$$B_A = 0.923\, B_B + (K/\pi) \int B(\theta, \varphi)\theta^{-2} \cos\theta \, d\omega = aB_B + bB_S, \quad (16)$$

where B_A = adaptation luminance in millilamberts;
B_B = luminance of test field in millilamberts;
B_S = maximum luminance existing in surround field, in millilamberts;
$B(\theta, \varphi)$ = luminance of surround field over elementary solid angle $d\omega$;
θ = angle in radians between line of sight to elementary spot $d\omega$ and line of sight to test field;
φ = angle measured about line of sight to test field;
$d\omega$ = elementary solid angle in steradians;
K = a constant = 9.6×10^{-3};
a, b = constants.

The formula assumes a test field of a diameter subtending an angle of 1.5 degrees (.026 radians) at the eye. This is illustrated by the field II in Fig. 10.

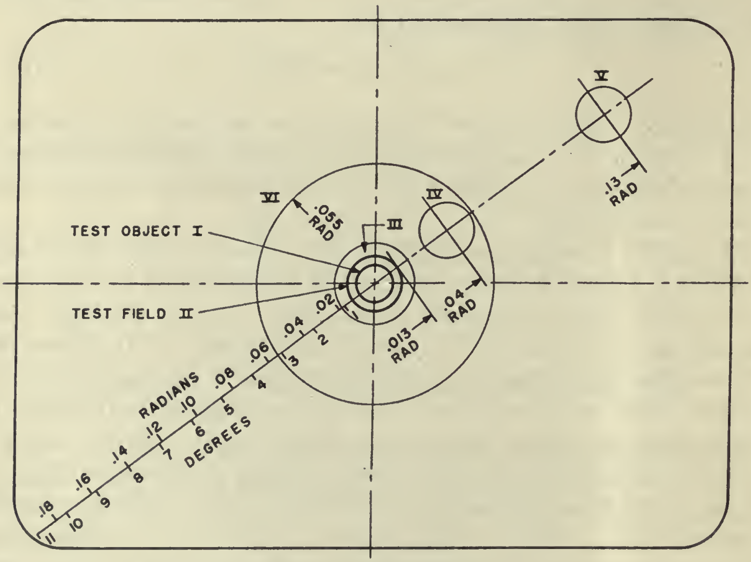


Fig. 10. Picture field.

The first equation assigns to a in the second equation a fixed value 0.923. The quantity b is a parameter measuring the character of the distribution of luminances in the surround field. It assumes its maximum value, namely 0.077, for a complete surround all at the lumi-

nance of the test field B_B. It approaches its minimum value of zero for a surround which is all physically black except for a small area of luminance B_S, and the value further falls rapidly as this area is removed from the line of sight. Some intermediate fields are illustrated in Fig. 10.

The value of b is 0.05 for a field of luminance B_S entirely surrounding the circle VI, the space within this, to the test field boundary, being physically black. Single areas of luminance B_S at the spots III, IV, and V give values of b respectively 0.01, 0.001, and 0.0001. Fig. 10 also shows the outline of a picture field, viewed at $D = 1$ with aspect ratio of 3 (height) to 4 (width).

Moon and Spencer specify the luminance of a test object enough lower than that of the test field to be just perceptible, and tell how this is influenced by the adaptation luminance. The test object subtends an angle of one degree, indicated by field I in Fig. 10. The formula breaks up into two cases according to whether the adaptation luminance is greater or less than the test field luminance.

In the first case, where

$$B_A = aB_B + bB_S \geqq B_B, \tag{17}$$

the threshold is reached at a value indicated by the empirical equation

$$B_B - B_o = \Delta B = c\,(A + \sqrt{aB_B + bB_S})^2, \tag{18}$$

where B_o = luminance of test object in millilamberts;
A = a constant = 0.255;
c = a constant = 0.143.

In the second case, where

$$B_A = aB_B + bB_S < B_B, \tag{19}$$

$$\Delta B = c\left[A + \frac{B_B}{\sqrt{aB_B + bB_S}}\right]^2 \tag{20}$$

A plot of the formula is illustrated in Fig. 11 in terms of the Fechner fraction (that is, $\Delta B/B$) as a function of the luminance B_B of the test field, for a variety of values of bB_S. The curves are in general given for integral powers of 10 for bB_S, but in one case b is given its maximum value (0.077) for a maximum surround luminance B_S = 10,000 millilamberts. The asymptotic value reached for $bB_S = 0$ is also illustrated.

As in the case of the Weber-Fechner law, it is possible to integrate the Moon and Spencer formula to obtain the total cumulation of perceptible steps in luminance, say from some maximum luminance

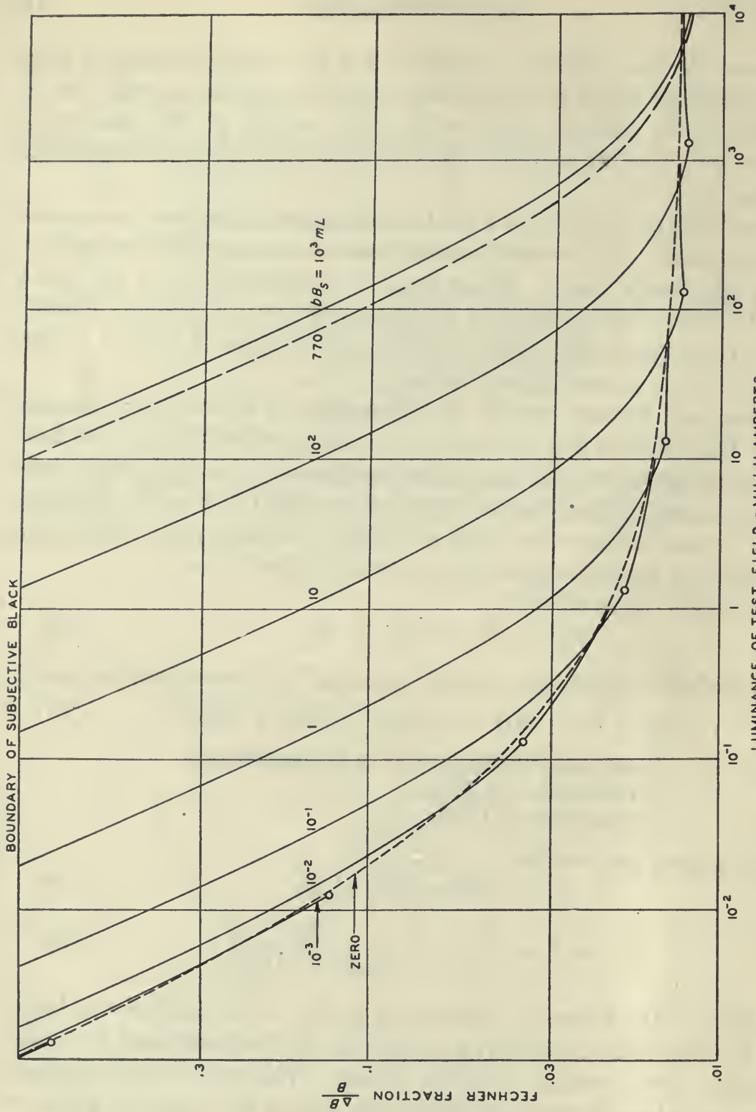


Fig. 11. Moon and Spencer formula for deviations from Weber-Fechner law.

of the test field B_B down to a lower specified value. This may be done by taking the approximate relationship

$$\frac{dS}{dB} = \frac{\Delta S}{\Delta B} \tag{21}$$

and putting $\Delta S = 1$ (to represent a single step), and by expressing

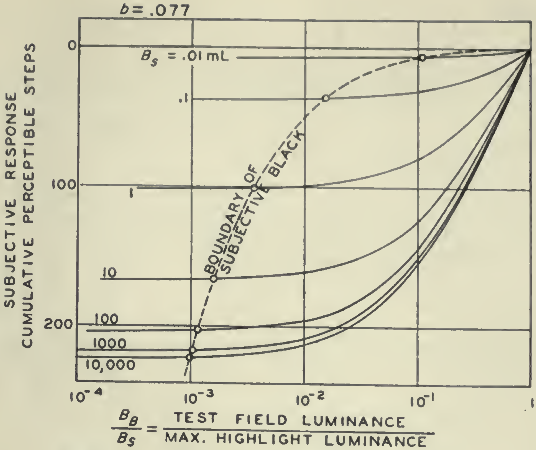


Fig. 12. Subjective Response (b = .077).

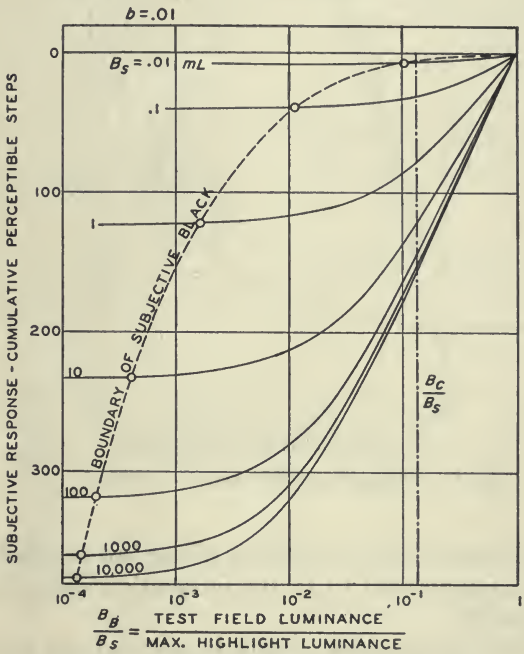


Fig. 13. Subjective Response (b = .01).

ΔB as a function of B_B from equations (18) and (20). Formally, this leads to:

$$S = \int dS = \int \frac{1}{\Delta B}\, dB = \int \frac{dB_B}{\Delta B(B_B)}\,. \qquad (22)$$

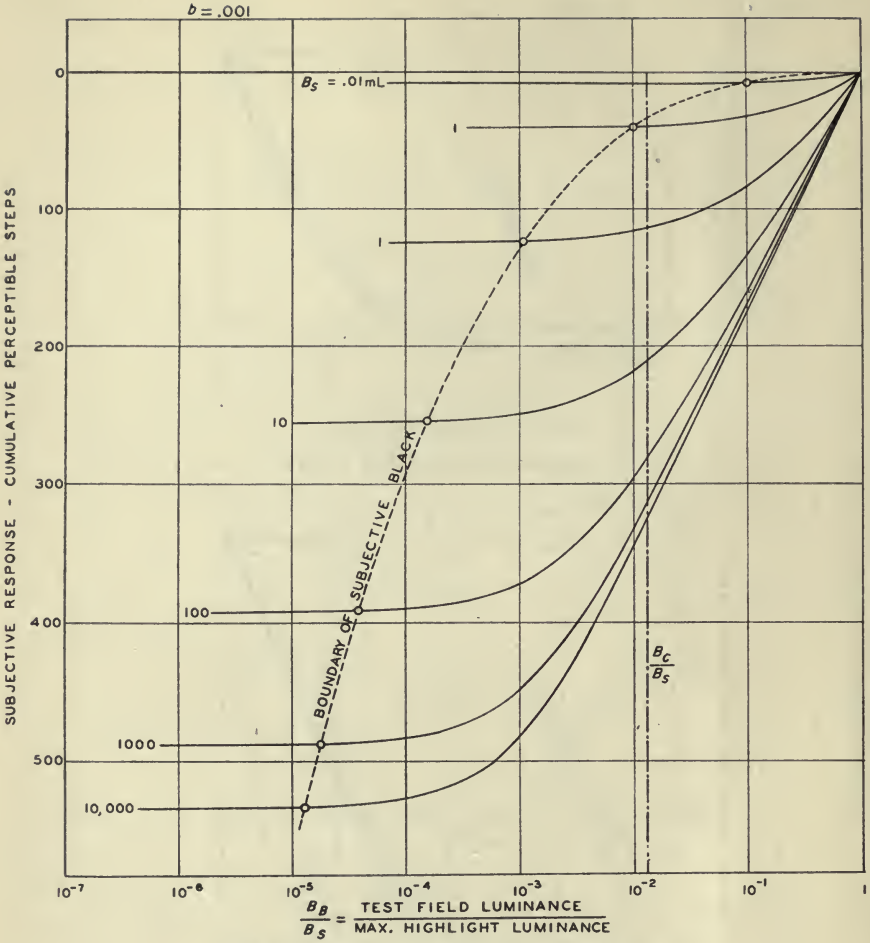


Fig. 14. Subjective Response ($b = .001$).

In the simpler case where the Weber-Fechner law is followed, that is, where ΔB is proportional to B, the integration yields the result given in equation (15).

Where the Moon and Spencer formula is assumed, the appropriate expression from equations (18) and (20) is introduced in the integrand. In this instance, the integration is rather laborious but straightforward. The results have been plotted in Figs. 12 to 15, inclusive, each plot being for a different assumed value of the parameter b. Each plot shows the cumulative perceptible steps from the maximum luminance value B_S in the field, down to a specified ratio B_B/B_S

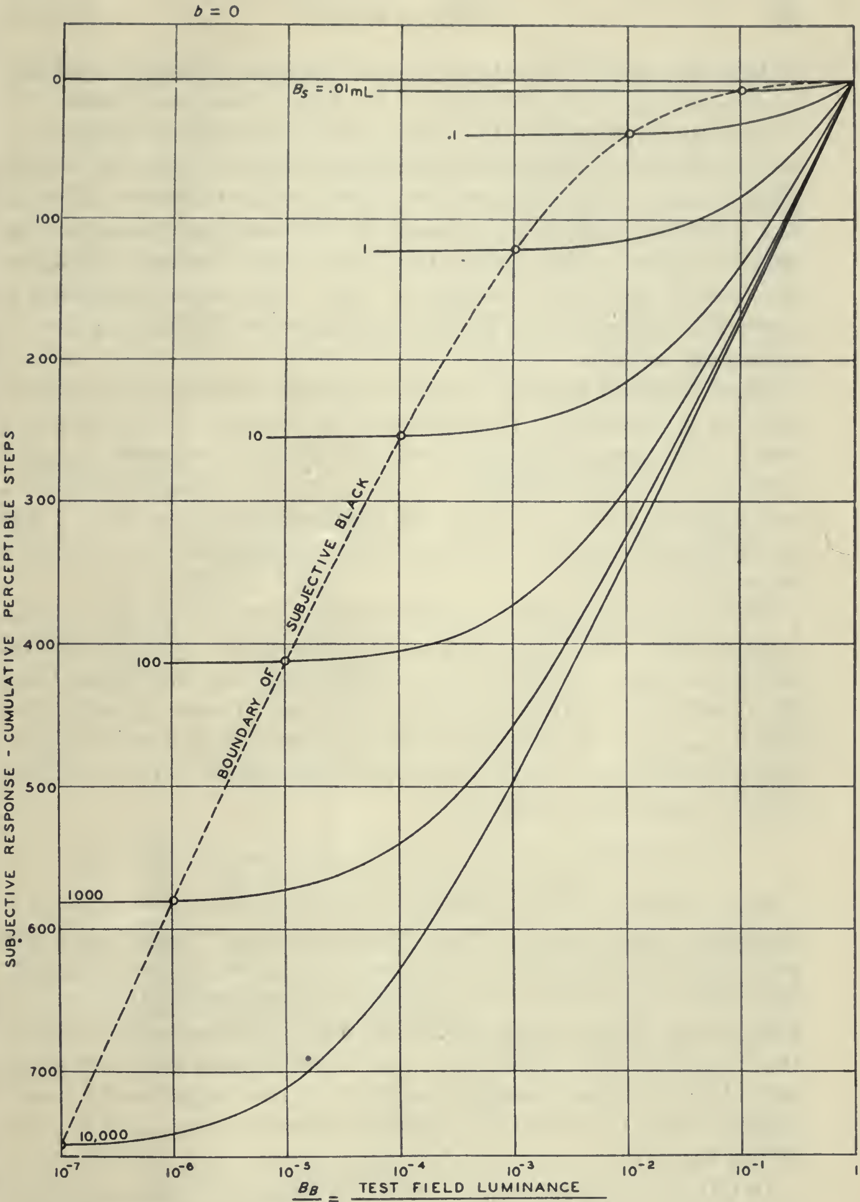


Fig. 15. Subjective Response ($b = 0$).

of this, for a variety of values of B_S as indicated. The plot is continued in each case to the approximate boundary of subjective black.

The curves from the Moon and Spencer formula have been compared with other determinations of the deviations from the Weber-Fechner law.[7] The agreement is not always too satisfactory, although this is undoubtedly in part caused by differences in viewing conditions, which are quite varied. In a general way, one can say that in the present state of knowledge the form of the formula proposed is reasonably adequate, but the constants used in it may be subject to some later revision.

The Moon and Spencer formula represents an important step forward in understanding the perception of contrast in the viewing of scenes and images. It, together with the Holladay principle, traces in a simple form the variations in this perception with picture content and highlight luminance level. The general qualitative facts of this are common knowledge, but the formula presents them in a compact expression.

The formula, of course, describes the perception of contrasts of areas of about photometric size, rather than grains of the size found in random noise. It has been found, however, that the vision of fine lines and areas is largely describable in terms of contrast perception in larger areas.[8] Thus the information on areas of photometric size is at least illustratively valid, and probably even more, in the consideration of random noise perception.

3. Influence of Signal to Luminance Translation

It is clear that the susceptibility to noise in the over-all system is dependent only upon the characteristics of the system beyond the point at which the noise is introduced, up to the ultimate viewing. Hence the only portion of the characteristic influencing the susceptibility of the system to the noise is the transfer characteristic between the electrical signal at this point and the final image luminance, with the subjective characteristics appropriate to the image viewing conditions. This is illustrated in two forms of presentation, parts (A) and (B) of Fig. 16.

In (B) the electrical signal is plotted in terms of db below the maximum signal. In (A) the electrical signal is plotted as the arithmetical ratio to the maximum signal. The luminance is plotted, in both cases, in terms of a hypothetical photographic density by which maximum

highlight luminance in the picture is attenuated, to equal the given luminance.

In (A) if a noise impulse is superposed on a given signal c, it increases it to d. The increment in signal, called ΔV, leads to an increment in luminance (measured in density units) called Δb. A given increment or decrement in voltage throughout the signal range appears as a constant displacement in the plot, represented by the two dotted lines.

In plot (B), on the other hand, a modulation of the signal which increases its level by Δv (measured in decibels), raises it from f to g, leading to an increment in the luminance from g to h, or Δb (measured

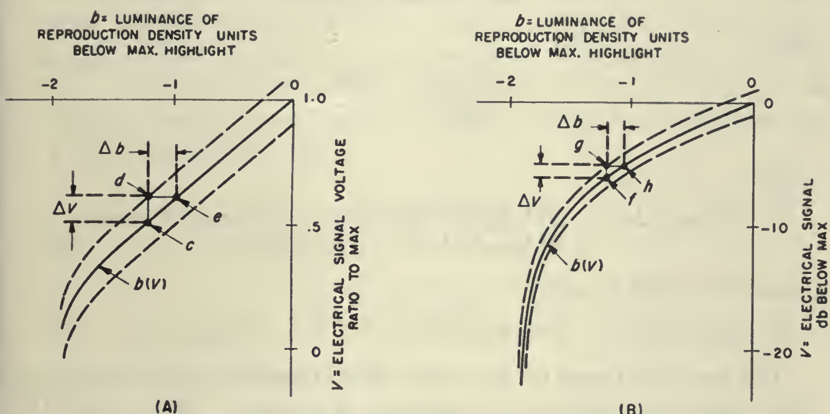


Fig. 16. Characteristic of reproducer.

in density units). This modulation, over the signal range, appears as a constant increment (or decrement if in the reverse direction), and is again represented by two dotted lines.

That is, additive noise leads to luminance changes (in density units),

$$\Delta b = (db/dV)\,\Delta V, \tag{23}$$

where ΔV = noise-to-signal amplitude ratio.

Modulation leads to similar luminance changes,

$$\Delta b = (db/dv)\,\Delta v, \tag{24}$$

where Δv = modulation (from undistorted signal) in decibels.

The quantities db/dV and db/dv are seen to be important in translating the respective electrical disturbances into image disturbances.[9] The first, namely db/dV, times a factor which will be explained, has been called the "interference sensitivity" of the reproducer. It is sometimes desirable to express equation (23) in logarithmic terms. It becomes

$$20 \log_{10}(\Delta b) = 20 \log_{10}(db/dV) + 20 \log_{10}(\Delta V). \qquad (25)$$

The last term on the right is now the noise-to-signal ratio in db. The term on the left can be rewritten in terms of the Fechner fraction $\Delta B/B$ as:

$$\Delta b = 0.4343 \ \Delta B/B$$

and

$$\frac{20 \ \Delta b}{8.686} = \frac{\Delta B}{B}.$$

Hence

$$\begin{aligned} 20 \log_{10}(\Delta b) &= 20 \log_{10}(20\,\Delta b/8.686) - 20 \log_{10}(20/8.686) \\ &= 20 \log_{10}(\Delta B/B) - 20 \log_{10} 2.30 \qquad (26) \end{aligned}$$

Equation (25) becomes:

$$20 \log_{10}(\Delta B/B) = 20 \log_{10}(db/dV) + 7.2 + 20 \log_{10}(\Delta V). \qquad (27)$$

The first two terms on the right, taken together, have been called the "interference sensitivity" measured in decibels. The term on the left is a measure of the Fechner fraction in decilums, as used in Figs. 5 and 8.

In an entirely analogous way, equation (24) can also be expressed in logarithmic terms. It becomes:

$$20 \log_{10}(\Delta b) = 20 \log_{10}(db/dv) + 20 \log_{10}(\Delta v). \qquad (28)$$

The last term on the right can be expressed with respect to $\Delta V/V$ as follows:

$$\Delta v = 8.686 \ \Delta V/V$$

or

$$20 \log_{10}(\Delta v) = 20 \log_{10}(\Delta V/V) + 18.8.$$

Hence the entire equation becomes:

$$20 \log_{10}(\Delta B/B) = 20 \log_{10}(db/dv) + 26.0 + 20 \log_{10}(\Delta V/V). \qquad (29)$$

The last term on the right now expresses how far below the signal, in decibels, is the modulation. The first two terms on the right, taken together, have been termed the "differential sensitivity" in decibels. The quantity on the left, as before, is a measure of the Fechner fraction in decilums.

The interference and differential sensitivities are presented for several elementary picture tube characteristics in Fig. 17. For three of those shown, the luminance of the reproduction varies as some power n of the input signal voltage. For the fourth, the luminance varies as the exponential of the voltage.

In order for comparisons between the four to be more meaningful, they have been so chosen that the signal voltage covers the same range, and gives the same finite luminance range (two photographic density units), for all the characteristics. This requires adding a small bias in some cases to the voltage, otherwise to zero voltage the luminance would range to minus infinity. The actual equations are, for the variation to power n

$$B = p(V + q)^n \tag{30}$$

where

$$\begin{aligned} q &= 1/\sqrt[n]{100 - 1}; \\ p &= (1/100q^n); \end{aligned}$$

and for the exponential variation

$$B = 10^{2V}/100. \tag{31}$$

The bias, q, is not shown in the right plot of Fig. 17, but it must be included in the computation of the db signal range in the plot on the left. This shows the influence of the factor p.

For these characteristics the interference and differential sensitivities are plotted in Fig. 18. Comment on these is reserved until their application, as illustrated in Fig. 19, is discussed.

Examination of equations (27) and (29) shows that if the Fechner fraction, for some grade of impairment (such for example as threshold) for a given type of noise or modulation is known, the tolerance on noise-to-signal ratio (in decibels) is simply the difference between the Fechner fraction expressed in decilums and the interference or differential sensitivity. If the Weber-Fechner law holds in the region of interest, the Fechner fraction is a constant and the tolerance is merely that constant less the proper sensitivity.

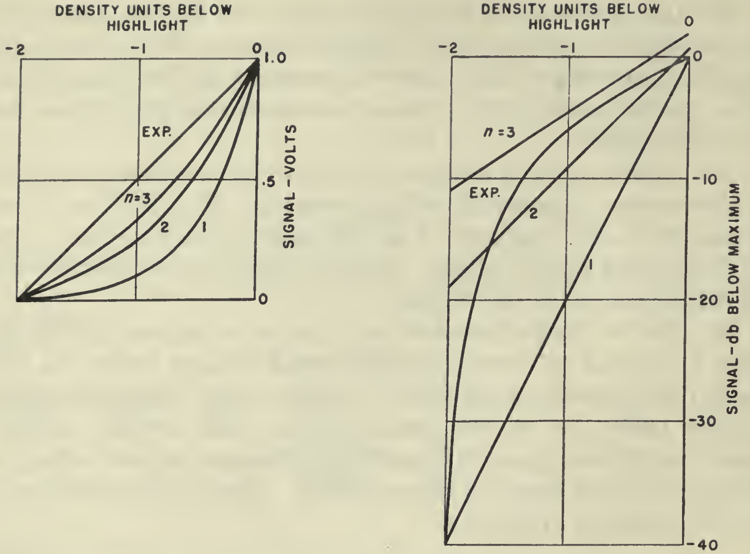


Fig. 17. Typical reproducer characteristics.

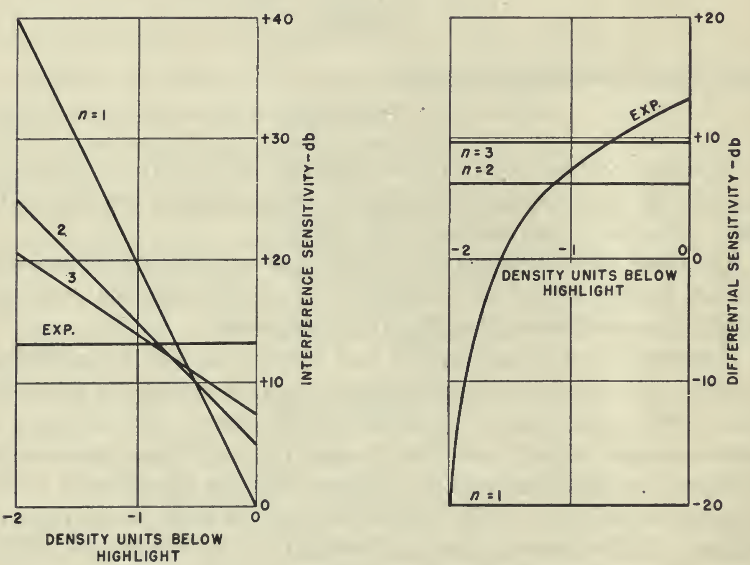


Fig. 18. Interference and differential sensitivities.

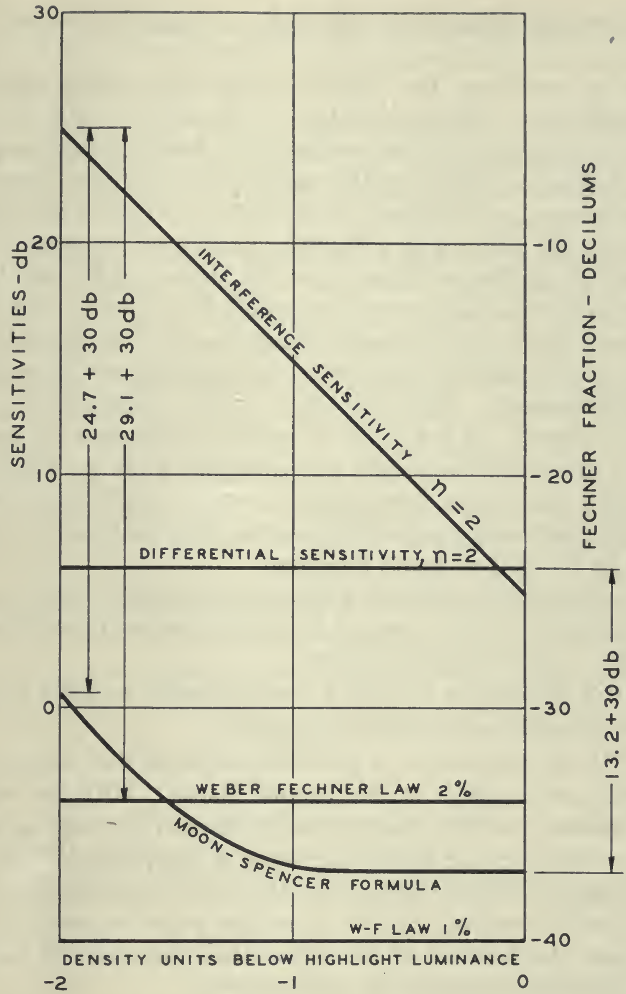


Fig. 19. Noise-to-signal requirements.

In Fig. 19 are plotted the Fechner fractions in decilums and the sensitivities (for $n = 2$) in decibels, over the picture luminance range which again is assumed as 100:1, or a photographic density range of 2. The scales on the Fechner fraction and sensitivities are offset 30 db, as shown, so that the curves may fall in approximately the same part of the plot. The Fechner fractions are shown at 2 per cent and 1 per

cent, assuming constancy in each case, following the Weber-Fechner law.

For such conditions, the additive noise will be visible only in the deep blacks ($b = -2$), and will have to be at 30 + 29.1 db = 59.1 db below the signal to be just visible with a Fechner fraction of 2 per cent. Modulation will be equally visible throughout the range of picture luminances, and will have to be at 30 + 10 = 40 db below the signal to be just visible with a Fechner fraction of 2 per cent.

Instead of the Weber-Fechner law the Moon and Spencer formula may be used, with the reservations which have already been noted. A plot is shown in Fig. 19, copied from Fig. 11 The parameter b of equation (16) is taken as equal to .01 and the highlight luminance B_S as 100 millilamberts. This gives $bB_S = 1$, and corresponds to a rather brightish picture. If the curve is assumed applicable to the noise threshold under consideration it indicates that while the noise will be most visible only in the deep blacks, it will be nearly as visible over about half the density range of the picture. At threshold the noise will be 30 + 24.7 = 54.7 db below the signal.

The modulation in this case will be about equally visible over the upper half of the density range of the picture, and at threshold will be 30 + 13.2 = 43.2 db below the signal.

With this illustration in mind it is now possible to make some general observations regarding Figs. 18 and 19.

1. With the assumption of the Weber-Fechner law, additive noise is generally most visible in the extreme blacks. With the exponential characteristic a limit characteristic is reached in which the noise is equally visible over the entire tone range of the picture. With deviations from the Weber-Fechner law, the noise susceptibility tends to be less sharply localized, and the maximum is apt to be shifted to the dark grays. In the limit of the exponential characteristic the maximum is broad and shifted to the white regions.

2. With the assumption of the Weber-Fechner law, modulation is generally equally visible over the entire tone range of the picture, although in the limiting exponential case the visibility is greatest in the extreme whites. With deviations from the Weber-Fechner law, modulation generally becomes visible over broad white regions or the extreme whites.

3. The characteristic for $n = 1$ gives, of those considered, the greatest susceptibility to additive noise, and the least to modulation.

4. As n is increased, the susceptibility to additive noise is reduced

while that to modulation is increased. The changes are slow beyond $n=2$. The two susceptibilities become approximately comparable in the limiting exponential case.

A diagram of the type of Fig. 19 is applicable for each case of the data of Figs. 5 and 8. Those particular data were taken with a flat field, hence each point corresponds roughly with the intersection of an appropriate Fechner fraction curve (either following the Weber-Fechner law or the Moon and Spencer formula) with the vertical axis at highlight luminance value. From the vertical distance to the appropriate picture tube characteristic it is possible to translate the ordinates of Figs. 5 and 8 to electrical signal to noise ratios for the near threshold condition. It is further necessary for setting tolerances on the noise, to determine the vertical distance between the two chosen curves, along the ordinate to the left of maximum highlight luminance corresponding to the maximum susceptibility to the noise.

The number and types of characteristics considered here are of course extremely limited. There are few receiving mechanisms that follow a pure law as assumed. In addition, negative modulation characteristics represent special problems. A more complete study of the subject should also include an examination of the point that, as the density range over which a given noise is rendered susceptible is increased, its general frequency of occurrence, and the geometrical area over which it is visible on any one picture, are both increased.

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An Improved Photomultiplier Tube Color Densitometer

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Summary—**Previously, attempts were made to modify black-and-white densitometers to make them suitable for color measurements, but considerable difficulty was experienced with such modifications. Therefore, the Ansco Laboratories developed new electronic circuits utilizing the full capabilities of the photomultiplier tube for this purpose. These developments, combined with other refinements, have made it possible to design a densitometer capable of using sharp-cutting filters to measure color densities up to 4.0 and over.**

Introduction

Until quite recently, the photographic industry has been concerned mainly with black-and-white reproduction. This situation is reflected in the attention devoted to black-and-white sensitometry. However, during the past few years, the importance of color products has risen rapidly and in the case of motion picture film there are numerous commercial color processes now on the market and the number of production releases on color is growing continuously. As a result of this trend there is a corresponding demand for appropriate testing and control instruments and techniques.

One important aspect of three-layer color-film sensitometry is the measurement of color densities of the processed test strips. In sharp contrast to black-and-white densitometry, wherein it is permissible to use the entire radiation from a given light source to excite the phototube receiver, in color densitometry it is desirable to make density measurements of the materials using narrow spectral-energy bands, preferably at single wavelengths. This requirement rules out the possibility of using relatively simple receiving systems of limited sensitivity or relatively inefficient optical systems—a luxury available only in black-and-white densitometery. When one confines the radiation to a desirably narrow band, he is confronted with a reduction of the available energy by a factor of 100 to 1000 or more before absorption by the specimen itself is even considered. Therefore,

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relatively drastic changes are necessary in the design of instruments which are required to do an equally good job in color as had previously been done in black and white.

EARLY COLOR DENSITOMETERS

In order to meet the problem of color densitometry, Evans proposed the use of a cleverly modified visual densitometer and reported it to this group.[1] Later, null techniques incorporating high-gain amplifiers of special design were used in some objective instruments to achieve the necessary sensitivity. Instruments of this type were too slow to use for routine work although they were satisfactory for some applications where the volume of work was relatively small. In order to overcome their disadvantages, at Ansco a direct reading black-and-white densitometer was modified in such a way as to provide the necessary high sensitivity and yet preserve its other major features.[2]

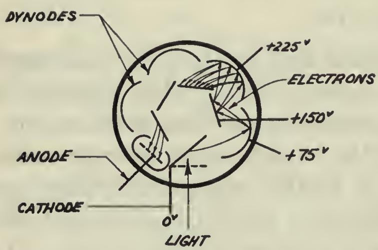

Fig. 1—Explanatory diagram of electron-multiplier-tube operation.

In this instrument an electron-multiplier type of phototube was substituted for the simple phototube used in the original. This new tube operates according to the principles shown in Fig. 1. For each electron emitted by the action of light on the cathode, on the average two or more electrons are emitted by secondary emission from each succeeding dynode element. Therefore, the input current is amplified many times when it reaches the anode. The use of the photomultiplier tube increased the sensitivity of the original instrument by a factor of 10,000 but it was necessary to take special precautions to shield and insulate the entire multiplier-tube supply and the multiplier tube itself because of unfavorable polarity relationships. In spite of a consequent tendency toward instability the instrument was put into routine use and it quickly demonstrated the value of a simple direct-reading densitometer in color development and color-control work.

In the course of further development work, a photomultiplier-tube circuit was devised which retained the high sensitivity of the modified instrument described above and in which the inherent stability was greatly improved. A compensating circuit was also developed which enables the user to calibrate the scale of the instrument to agree closely with virtually any desired reference standard.

MULTIPLIER-TUBE FEEDBACK DENSITOMETER

Photomultiplier tubes have acquired a reputation in some circles for instability. This is because many mutliplier tubes, when operated at a constant dynode voltage, show pronounced fatigue at even moderate light levels.[3] If one attempts to cover a density range of 0 to 3 by conventional use of the photomultiplier tube he often encounters fatigue at the high light levels (low densities) and dark current at the lowest light levels (high densities). It is known that the fatigue effects are most serious in the last few dynode stages and occur whenever the current is of large magnitude and changes appreciably. *In the present case the anode is operated at a constant-current level and the last few dynodes are operated at comparatively constant currents regardless of the densities being measured.* Therefore, the stability of the circuit is comparable to that of a multiplier tube operated in conventional circuits, but maintained under ideal optical and electrical conditions; namely, at constant dynode voltage and with a constant level of incident flux.

Furthermore, when operated in conventional circuits, photomultiplier tubes require a precision-stabilized high-voltage source. The present circuit completely avoids the necessity for such a source.

BASIC CIRCUIT*

The basic operating principles of the photomultiplier-tube circuit can best be demonstrated by reference to Fig. 2. In this illustrative circuit the operator manually adjusts the voltage applied to the multiplier dynodes in such a way as to keep the multiplier-tube output current constant at all light levels. When a given specimen density is inserted in the light beam, the multiplier-tube output current is at first reduced but is then restored to its original value by increasing the dynode voltage. A voltmeter which responds to the dynode voltage applied to the tube can be calibrated in terms of density and

* Protected by United States Patents 2,478,163 and 2,457,747. Patents on other novel features are pending.

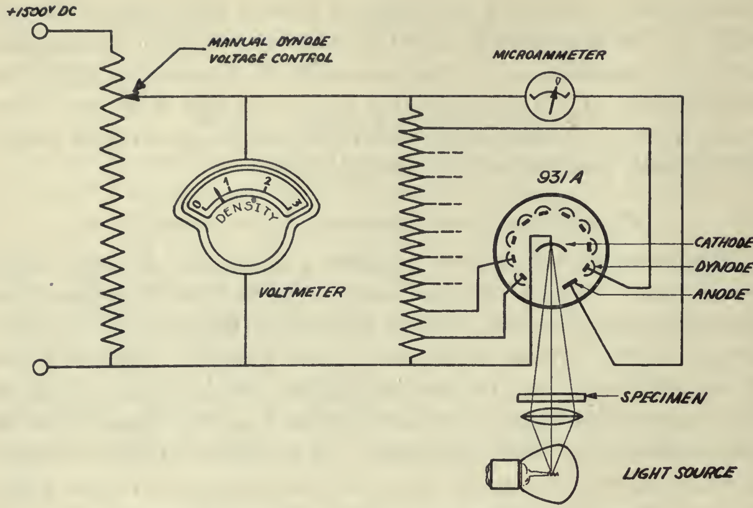

Fig. 2—Illustrative dynode-voltage-feedback circuit.

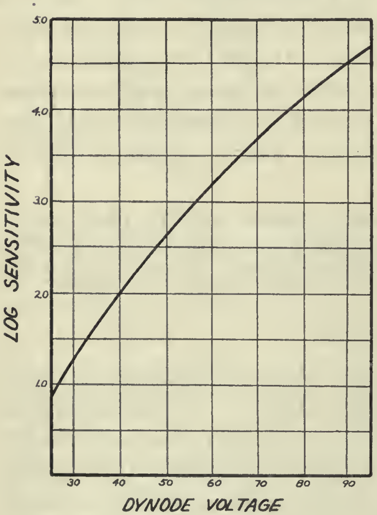

Fig. 3—Relationship between dynode voltage and log (sensitivity) for a typical photomultiplier tube.

the scale will be fairly uniform since the relationship between phototube sensitivity and dynode voltage is virtually logarithmic† as shown in Fig. 3. In actual practice an electronic tube performs the dynode voltage adjustment automatically and instantaneously. Therefore, in effect the sensitivity of the multiplier tube is continuously adjusted so that when the light intensity is high the gain of the tube is low and vice versa. The product of light intensity and tube sensitivity is at all times constant.

Fig. 4 is a simplified schematic diagram of the densitometer circuit. The voltage applied to the 931-A photomultiplier-tube dynodes is derived from the drop across

† Density, $D = \log_{10} (1/F) = \log_{10} (0)$. In which unit flux is incident on the specimen, F is the flux transmitted, and 0 is the opacity of the specimen.

the cathode resistor R of the type 807 control tube. This voltage is controlled by the grid G whose potential is determined by the anode current of the photomultiplier tube (by virtue of the voltage drop it creates across the grid resistor R').

The electrical-polarity relationships are such that, as illustrated, an increase in illumination on the phototube causes the voltage across R to drop and therefore the effective sensitivity of the 931-A tube to decrease. This negative-feedback action is continuous and therefore the voltage developed across R is a reliable measure of the phototube

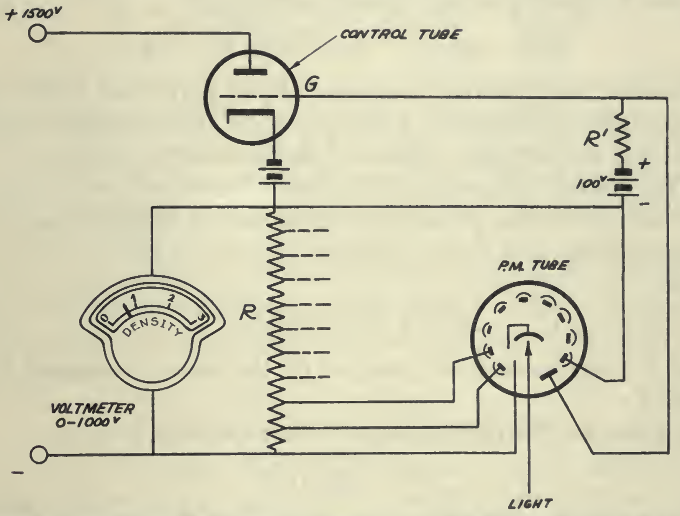

Fig. 4—Simplified schematic diagram of multiplier-tube feedback densitometer.

illumination. A few of the specific advantages obtained from the use of this circuit are: 1. High sensitivity with high stability. 2. An approximately logarithmic electrical response over a wide range of light levels. 3. Reduction of photomultiplier-response fatigue. 4. Elimination of the need for a stabilized high-voltage power supply.

THEORY OF OPERATION

Dynode Voltage Versus Density Relationship

From the qualitative description of the instrument given above it will be recognized that the uncompensated output of the instrument

portrays the relationship between dynode voltage and photomultiplier-tube sensitivity. The equation,

$$S = k \cdot E^{n/2} \tag{1}$$

where S = net sensitivity of tube in terms of anode current per unit incident radiant flux
k = a constant, characteristic of the tube
E = dynode voltage
n = number of stages

is often used to express this function* but it is not immediately apparent that E versus S is even quasi logarithmic,

$$\text{since} \quad \log_{10} S = (n/2) \log_{10} E + \log k.$$

However, the following treatment shows that when $n/2$ is large, the relationship between E and $\log S$ approaches linearity over the finite range of operating values of S encountered in practice.

In the present discussion it is assumed that the anode current is held constant in the presence of variations in incident flux on the photomultiplier tube by control of the dynode voltage.

Thus

$$F \cdot S = K \text{ or } S = K/F \tag{2}$$

where F is the radiant flux received by the photosurface and K is a constant.

By definition, the optical density of the specimen is

$$D = \log_{10} (1/F)$$

where unit flux is incident on the specimen and F represents the transmitted flux received by the phototube and from (2) in the present circuit

$$\log S = \log K + (\log (1/F) = D)$$

from (1)

$$\log S = \log k + n/2 \log E$$

$$\therefore \quad D = n/2 \log E + K' \tag{4}$$

where

$$K' = \log k - \log K$$

* C. C. Larson and H. Salinger, "photo-cell multiplier tubes," *Rev. Sci. Instr.*, vol. 11, pp. 227; July, 1940. The fundamental photomultiplier tube equation is $S = k \times G^n$, in which G is the gain per stage.

and

$$dD/dE = (n/2)\,(\log_{10} e)\,(1/E). \tag{5}$$

The ratio of the slope (dD/dE) taken at a specimen density of 2.0 to that taken at density 0.0 is a convenient measure of the "linearity" of the system. Letting M represent this ratio,

$$M = \frac{(dD/dE)_{D=2.0}}{(dD/dE)_{D=0.0}}; \text{ from (1)} \quad E = (k/S)^{-2/n}$$

therefore
$$M = \frac{[(n/2)(\log_{10} e)(k/S)^{2/n}]_{2\cdot 0}}{[(n/2)(\log_{10} e)(k/S)_{0\cdot 0}]^{2/n}} = \left(\frac{S_{0\cdot 0}}{S_{2\cdot 0}}\right)^{2/n} \tag{6}$$

which shows that as the number of dynode stages n *increases,* M *approaches unity as a limit and the voltage is linear with density.*

In the 931-A tube $2/n \cong 0.23$ and if $D_0 = 0$ and $D_2 = 2.0$, $(S_0/S_2) = 1/100$. Under these circumstances $M = 0.36$, whereas for a conventional circuit operated at constant dynode voltage $M = 0.01$ for the same density range.

The compensating circuit described in a subsequent section provides the correction necessary to maintain a constant slope of the dynode voltage versus density curve over the operating range of the densitometer.

FEEDBACK-AMPLIFIER PERFORMANCE

It was stated earlier that the performance of the instrument is unaffected by ordinary variations in the high-voltage power supply. This fact will become evident from the following proof of independence of the instrument's performance with respect to changes in the amplifying characteristics of the control tube.

In Fig. 5* the photomultiplier tube is shown as P. E represents the voltage developed across the dynode resistors of resistance R. I is the 807 control tube plate-cathode current. E_b is the voltage developed across the gaseous stabilizer tube of the actual circuit and is here represented as a battery to provide a suitable operating potential between the photomultiplier-tube anode and dynode No. 9. E_c is the voltage applied to the photomultiplier-tube load resistor r and is referred to ground. The photomultiplier anode current is

* In the actual circuit, a cathode-follower tube is inserted between point X and the 807 grid but it has no significant effect on the analytic behavior of the basic circuit treated here.

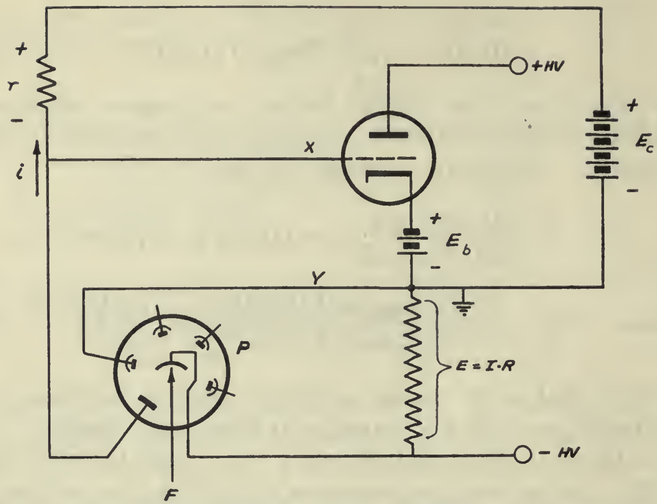

Fig. 5—Explanatory diagram which illustrates the analytical behavior of the dynode-voltage-feedback circuit.

i and F is the flux incident on the photo cathode. As drawn, the following relationships apply:

$$\begin{bmatrix} E_g = E_{xy} - E_b \\ E_{xy} = E_c - i \cdot r \\ E_g = E_c - E_b - i \cdot r = E_a - i \cdot r < 0 \end{bmatrix} \tag{7}$$

where

$$E_a = E_c - E_b.$$

Since the sensitivity, S, of the photomultiplier tube may be defined as

$$S = i/F, \text{ then (from (1)) } i = F \cdot k \cdot E^{n/2}$$

and

$$E = I \cdot R = (g_m \cdot E_g) \cdot R \tag{2}$$

where

$$g_m = \left(\frac{\partial I}{\partial Eg}\right)$$

then

$$E = g_m \cdot R[E_a - F \cdot k \cdot r \cdot E^{n/2}] \tag{8}$$

and

$$\partial E/\partial F = [-k \cdot r \cdot E^{n/2} - (n/2) \cdot F \cdot k \cdot r \cdot E^{(n/2)-1}\,\partial E/\partial F]g_m \cdot R$$

$$= \frac{-g_m \cdot R \cdot k \cdot r \cdot E^{n/2}}{1 + n/2 \cdot F \cdot k \cdot r \cdot E^{n/2-1} \cdot g_m \cdot R}$$

$$= \frac{-k \cdot r \cdot E^{n/2}}{(1/R \cdot g_m) + n/2 \cdot F \cdot k \cdot r \cdot E^{n/2-1}}. \quad (9)$$

Equation (9) shows that if $(R \cdot g_m)$ is large, the relationship between E and F will be independent of R and g_m. Furthermore, since variations in the high-voltage supply to the 807 control tube can effect the circuit only by changing the effective value of g_m, the present circuit likewise is independent of fluctuations in the 807 plate-supply voltage.

Compensating Circuit

As mentioned in the introduction, a convenient optical system of arbitrary geometry and relatively high efficiency was adopted but the resulting density values obtained, particularly with scattering specimens, do not perfectly conform with those obtained according to techniques prescribed by the American Standards Association for the determination of Diffuse Density.[4] For this reason alone it would be desirable to provide some automatic scale compensating feature. In addition, the fact that the relationship between E and ($\log F$) is not quite linear in the case of the 931-A makes such a feature even more desirable since it can be used to correct both distortions simultaneously.

Therefore, a circuit was developed which corrects the output voltage in such a way as to give a close approximation to the desired calibration ($\pm$ 0.02 over the density range 0.0 to 3.0). Its basis of operation is illustrated in Fig. 6.

The output meter 0 measures the total dynode voltage AB with the indicated electrical polarity so that Z is always negative with respect to A and the magnitude of the voltage E_{AZ} is of course directly proportional to the current flowing through R_2.

Now if there were no compensation, the family of possible specimen-density versus meter-reading curves which could be obtained by control of shunt S is shown in Fig. 7, where curve A represents the lowest shunt resistance and curve F the highest. The heavy straight line represents the ideal relation. It will be noted that curve E gives reasonable agreement with the ideal values over the density range 0 to 0.5.

If it were possible in the case of curve E to readjust continuously

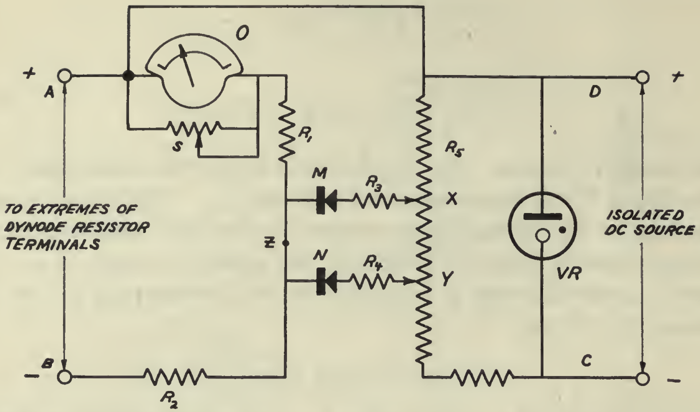

Fig. 6—Circuit which provides corrective action resulting in a uniform relation between specimen density and meter current.

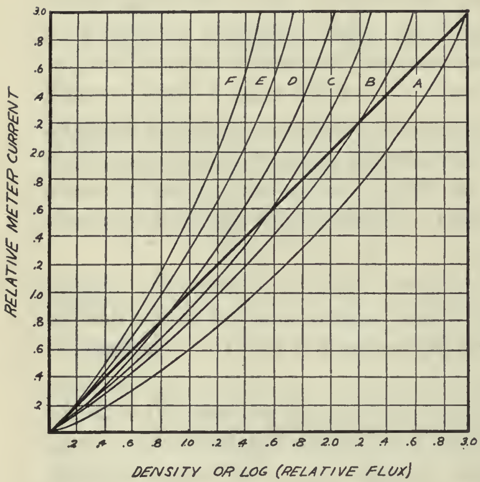

Fig. 7—Family of specimen-density versus meter-current curves obtained by varying shunt resistor S of Fig. 6.

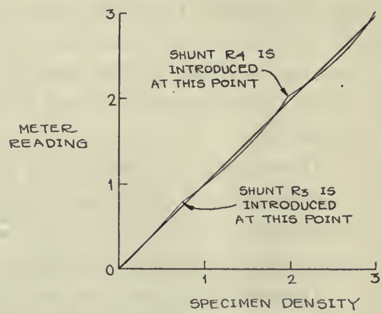

Fig. 8—Comparison of relationship between specimen density and resulting meter current after compensation. (Errors exaggerated for illustrative purposes.)

the shunt S to a lower resistance value at all points corresponding to density 0.5 and above, it is clear that the approach to the ideal relation could be extended over a wider density range.

This is done, in effect, by the action of the compensating circuit shown in Fig. 6. Voltage E_{AZ} rises continuously with increasing density. Voltage V_{CD} is stabilized by the voltage-regulator tube and resistor R_5 is a relatively low impedance unit. If the variable tap

of R_3 is so adjusted that voltage E_{AZ} = voltage E_{AX} when the specimen density is 1.0 then at all higher densities (and therefore higher E_{AZ} voltages) rectifier M will pass current because the voltage difference E_{XZ} will be of proper polarity for conduction. Furthermore, if rectifier M is of low resistance it may be regarded as a switch which closes whenever voltage E_{AZ} exceeds E_{AX} and opens when E_{AZ} is less than E_{AX}. Under these conditions whenever the specimen density rises above 1.0, R_3 will act as a shunt path for the meter and if its value is properly selected a curve of the type shown in Fig. 8 between 0 and 2 will result. The range of satisfactory calibration may thereby be extended to cover the range 0–2. The correction is automatic, reliable, and instantaneous.

By adjusting the variable tap of R_4 so that voltage $E_{AZ} = E_{AY}$ when the specimen density is 2 the correction can be extended up to density 3. The number of corrective steps that *could* be used obviously is unlimited. However, two such shunts perform the correction satisfactorily.

Thus the compensating circuit provides an output current that is linear with density, making the instrument uniquely suited for automatic linear density recording by connecting the output to any standard ink recording milliammeter.

The circuit used in the actual instrument incorporates two independent sets of compensating circuit elements. One set is used when reading the densities of ordinary silver images and is adjusted at the factory so as to give results which are in approximate agreement with those obtained by ASA Diffuse-Printing-Density Type P-2b.* The second set is adjusted so as to give results which are in agreement with those obtained by a proposal submitted to the ASA for color densitometry.† A switch located on the right-hand side of the case permits

* In spite of the fact that the geometry of the optical system does not conform with that under which primary diffuse printing density measurements of the American Standards Association are made, the agreement has been shown to be sufficiently good for samples of widely different grain size as to permit the small errors to be ignored in routine sensitometric work. Specific data concerning the differences resulting from the use of an instrument incorporating a similar optical system have been reported earlier.[5]

† The order of the agreement obtained in this way is considered satisfactory for routine photographic sensitometry. Departures from the ideal values are kept at a minimum by virtue of the fact that the dyes used in most commercial processes are not sufficiently sharp cutting to cause serious errors in the results in the present case where the spectral purity of the source-filter-receiver combination is relatively high.

the selection of either circuit. The principal reason which necessitates using two circuits is the difference in diffusion between the silver and color film specimens; i.e., silver images have a relatively high scattering power whereas ordinary color-film samples scatter little light and the corresponding differences in effective density versus standard density require different degrees of compensation. Either one or both sets of controls can be readjusted, in a matter of minutes, to bring a given instrument into agreement with values obtained by the use of some other standard.

In its commercial form the bias points X and Y are both adjustable by potentiometers as are also resistors R_3 and R_4. This involves eight controls in all, which are accessible through a door on the right-hand side of the instrument case.

When used as a photometer for measuring external light levels or as a reflection densitometer, it is desirable to have the meter respond uniformly to uniform changes in log (incident flux). This requirement is well satisfied when the compensating circuit switch is placed in the "color" position.

FATIGUE REDUCTION

"Fatigue" is an undesirable characteristic of many electronic processes. As an example, when one irradiates a barrier-layer photocell with bright light the initial output current may be relatively high, but the response usually will fall off (exponentially) with time until eventually it reaches a stable value.

In the case of the electron-multiplier phototube similar effects may be found which are attributable to the fatigue of the secondary emissive dynodes. Although the photosurface itself may contribute to the over-all fatigue effect too, this is not the usual case in photomultiplier-tube operation because the level of incident radiant energy is very low.

Qualitatively, the benefits of the feedback circuit, as a means for reducing fatigue, may be appreciated by the following argument:

1. In practice, virtually any electronic device such as a multiplier tube will provide a stable output after a given time if all pertinent operating conditions are held constant. In the present case if the dynode voltage is stabilized and the incident flux on the photosurface is held constant, after a certain period the anode-current output will reach an equilibrium value.

2. Fatigue effects (which in photomultiplier tubes are confined to

the dynodes) will be some function of recent changes in electron bombardment of each of the dynodes involved. This is of course equivalent to a statement that the yield in secondary-emission ratio depends on the immediate history of the incident bombardment current on the dynode surface. It can therefore be appreciated that the magnitude of the fatigue in any specific case is a function of the magnitude of the disturbance from previous equilibrium conditions.

3. In the conventional or constant dynode voltage operation each dynode experiences major changes in bombardment current which are directly proportional to the changes in the flux level incident on a phototube. In the case of inverse-feedback operation the change in initial bombardment current for any given dynode, for an identical change in incident radiation on the photosurface, is less than in the constant dynode voltage operation case because the dynode voltage is always simultaneously changed in such a direction as to tend to maintain the dynode currents constant.

4. If now, we plot, for the inverse-feedback operation case a curve which relates dynode voltage to incident flux and consider any particular point on the curve, an arbitrary displacement along the curve will correspond to a specific change in flux level and a specific change in dynode voltage. Or conversely, if as the result of fatigue effects the tube sensitivity is reduced to a fixed amount, the change in dynode voltage necessary to restore the original output can be determined readily. Therefore, it is convenient to think of the changes in voltage in the inverse-feedback operation case in terms of the equivalent changes in incident optical flux.

5. Since in every case where comparable conditions of incident flux exist inverse-feedback operation will result in smaller corresponding changes in dynode bombardment current than in the constant dynode voltage operation case, the consequent fatigue effects, (as measured in terms of the increase in flux level necessary to restore the initial anode current in the case of constant dynode voltage operation and the initial dynode voltage in the case of inverse-feedback operation), will also be less.

The above analysis demonstrates the superiority of inverse-feedback operation qualitatively. In the following quantitative analysis, it will be shown mathematically that the difference between dynode bombardment currents in the case of constant dynode voltage operation and inverse-feedback operation is negligible for the first five or six stages but that in subsequent stages the difference becomes

significant. It is assumed throughout this discussion that in the case of inverse-feedback the amplification of the control tube is infinite and therefore that the photomultiplier-tube output current is constant regardless of the incident-flux level.

The analytical expressions for the anode current, as a function of fatigue, are as follows:

For either constant dynode voltage or inverse-feedback operation

$$\begin{aligned} I_t &= I_{P.C.}\cdot[G_1'\cdot G_2' \ldots G_9'] \\ &= I_{P.C.}\{G[1 - k\cdot q_{P.C.}(1 - a^{-t})]\cdot G[1 - k\cdot q_1(1 - a^{-t})]\ldots G \\ &\qquad\qquad [1 - kq_8(1 - a^{-t})]\} \\ &= I_{P.C.}\,[G(2 - \beta_1)\cdot G(1 - \beta_2) \ldots G(1 - \beta_8)] \end{aligned}$$

I_t = anode current at time t

$I_{P.C.}$ = photosurface current produced by incident flux

G_1', G_2' ... G_9' = gain of each dynode after elapsed time t

G = gain per stage before onset of fatigue and is assumed to be the same, initially, for all dynodes

β = "fatigue factor" and in this case is chosen equal to $k\cdot q\cdot(1 - a^{-t})$ where

k = a constant which determines the upper limit (G_n') to which dynode stage n will fatigue when $t = \infty$

q = a function of the current bombarding the particular dynode in question and therefore depends on the product of the preceding terms of the equation.

In this case it is chosen as equal to Δi_n where i_n represents the bombarding current for the nth dynode.

a = a constant which determines the rate of fatigue with time

t = the time elapsed since the onset of fatigue

The ratio of the initial to final outputs is

$$R = \frac{I_\infty}{I_0} = \frac{I_{P.C.}\cdot G^2(1 - kq_1)\cdot G(1 - kq_2) \ldots G(1 - kq_8)}{I_{P.C.}\cdot G^9}$$

$$= (1 - kq_1)(1 - kq_2) \ldots (1 - kq_8).$$

Let R' be a measure of the decrease in fatigue and equal

$$\frac{R_{CDO}}{R_{IFO}} = \frac{[(1 - kq_1)(1 - kq_2) \ldots (1 - kq_8)]_{CDO}}{[(1 - kq_1)(1 - kq_2) \ldots (1 - kq_9)]_{IFO}},$$

where R_{CDO} = the ratio R, above, for the case of constant dynode voltage operation and R_{IFO} is for the inverse feedback case.

Now if $k = 0.1$ and β is taken as $[0.1(\Delta i/i)(1 - a^{-t})]$* and a change of illumination of 1:1000 is considered, then

$$R' = \frac{(1 - 0.1)^9}{(1 - 0.1)^6(0.91)(0.92)(0.95)} = 0.88.$$

The treatment is considerably simplified if we allow the time t to approach infinity and confine our attention to initial and final values of output which result from a given change in flux level. It is also convenient to ignore the small change in β which takes place as a consequence of the slight reduction in actual bombardment currents during the fatigue process itself. With these simplifications, for a change in incident light of 1:1000, in the constant dynode voltage operation case the output will fatigue to 0.37 of its initial value whereas in the inverse-feedback operation case the output will fatigue to only 0.43 of its initial value. Therefore, operation of the tube in an inverse-feedback circuit represents a definite improvement with respect to fatigue of 1:0.88. It should be noted that in the treatment of the inverse-feedback operation, the anode current output is investigated as though no feedback were present, once the total level of the incident flux has changed to its new level and the general magnitude of the corresponding dynode-amplification factors have been established.

From the above discussions it is clear that feedback operation presents a real advantage from the standpoint of fatigue at all light levels although its advantage in this respect is greatest when extremely large differences in operating flux levels are involved.

CIRCUIT DETAILS

Fig. 9 shows the actual circuit. The high-voltage power supply for the multiplier tube is conventional but it is not stabilized since the associated control circuit automatically compensates for line-voltage fluctuation. A Type 807 beam-power pentode serves as the control tube for the dynode voltage. Its plate-cathode circuit includes the dynode-voltage dropping resistors which divide the total dynode voltage into equal increments for distribution to the individual dynodes. A 12SF5 triode is inserted between the photomultiplier-tube anode circuit and the 807 control grid and acts as a cathode follower. The operating conditions of the 12SF5 are such that its grid current is at all times less than 10^{-8} ampere yet its output impedance is low enough that the development of slight grid current during the life of the 807 control tube will not disturb the performance of the instrument as a whole.

* Results obtained for R' with this value of β are very nearly the same as those obtained with $\beta = k\,(\Delta i)(1 - a^{-t})$ and $\beta = k(i\Delta i)(1 - a^{-t})$ since the β values for the first 6 stages are nearly identical. The electron bombardment of the first dynode stage *is* identical for both inverse-feedback and constant dynode voltage operation at equal light levels.

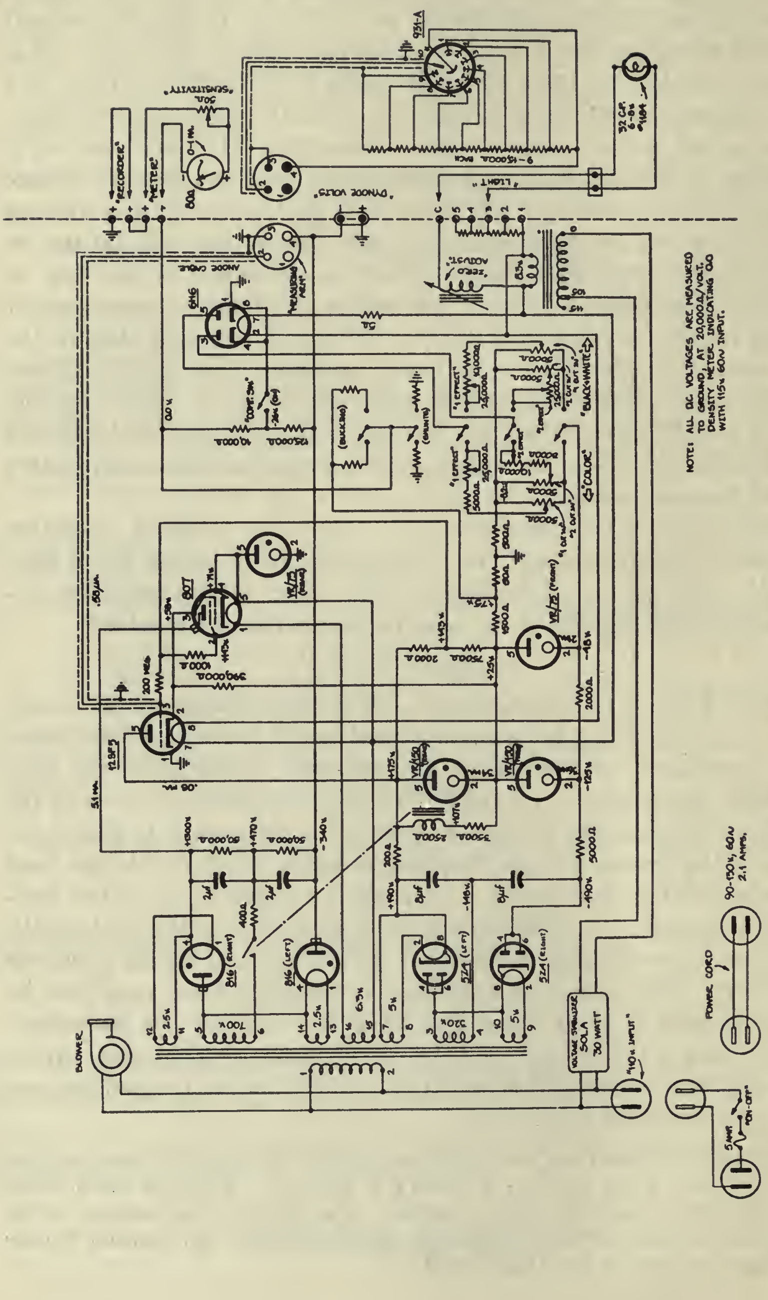

Fig. 9—Wiring diagram of Ansco Color densitometer Model 12.

Experience shows it is desirable to operate the multiplier tube with a constant dynode No. 9-to-anode voltage of between 50 and 80 volts. A constant-voltage gas tube, inserted between the 807 cathode and dynode No. 9 terminal, performs this function satisfactorily. Over the entire operating range of the device the voltage swing of the photomultiplier tube anode-to-807 cathode is less than 5 volts. Since the 807 cathode-dynode No. 9 voltage is sensibly constant the photomultiplier tube anode-to-dynode No. 9 voltage swing is only slightly more than 5 volts.

If the voltage applied to the photomultiplier anode load resistor is sufficiently high the anode current will automatically be held nearly constant throughout the operating range of the instrument. The voltage actually applied is more than 100 volts and therefore the variation in anode current is of the order of only 5 per cent.

It is necessary to provide a "bucking current" to counteract the current developed in the dynode-voltage-measuring circuit when there is maximum incident flux or zero specimen density (minimum dynode voltage). This is conveniently obtained from the stabilized 807 screen-voltage supply. The bucking current is approximately 2 milliamperes and the normal range of applied dynode voltage is 30 to 90 volts per stage.

The theory of the compensating circuit has already been discussed. A type 6H6 twin-diode vacuum rectifier serves its purpose in this circuit very well since it has relatively low forward resistance and passes negligible reverse current. All resistors except the photomultiplier anode load resistor are wire-wound.

To provide power for various attachments, stabilized low voltage is accessible through a door located at binding posts at the rear of the instrument.

Depending upon the sensitivity of the individual instrument, the lamp is connected to its source through different taps of a resistor. In all cases, stepless control of lamp brightness is affected by operation of a gear-driven solenoid which serves as a "zero" control. The output meter is a standard Weston Model 273 fan-shaped milliammeter having a long scale and high speed of response.

The basic instrument is believed to provide the highest sensitivity of any general purpose commercial photometer,* and there are many desirable ways in which this feature can be used. In the present case,

* The average Model 12 densitometer reads full scale (density 3.0) with an excitation of only 0.1 microlumen of energy 2870 degrees Kelvin.

this sensitivity is used principally to incorporate sharp cutting, but very dense, gelatin-foil filters in the path of the light beam in order to obtain high spectral purity without resort to monochromators, interference filters, gaseous discharge sources, or the like.

Optical System

With reference to Fig. 10, light from a 6-volt concentrated filament automobile lamp, controlled as indicated in the preceding section, is collimated by an aspheric lens after passing through a glass infrared absorbing filter. The beam then passes through a liquid cupric chloride filter which absorbs the radiation of wavelengths greater than 645 millimicrons but transmits virtually all of the shorter wavelength radiation. A second condenser focuses the beam on a 3-mm diameter aperture mounted in the top plate of the instrument proper. After partial absorption by the specimen the light is further absorbed by the "color filter" and is finally intercepted by the photomultiplier-tube cathode surface. The "color filter" actually consists of a pack of several small gelatin-foil filters which serve to confine the continuous spectrum of energy emitted from the tungsten source to each of the desired wavelengths. There are six sets of filters, each set being located over a different aperture in a "filter cylinder" surrounding the phototube.

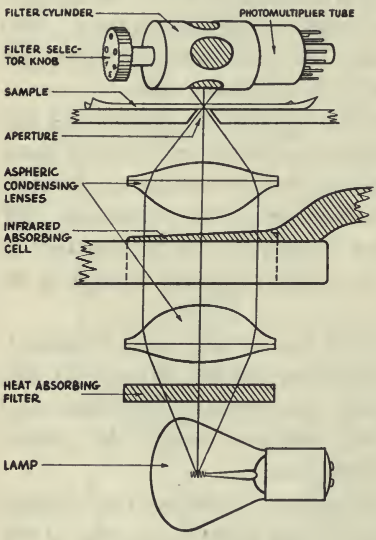

Fig. 10—Optical system of Ansco Color densitometer.

In one position a red-filter pack is used which serves to absorb radiation of wavelengths shorter than 644 millimicrons. In this case, the cupric chloride filter serves as the long-wave absorber with the result that the radiation reaching the photosurface is nearly pure spectral energy of 644 millimicrons wavelength.

In another position the filter pack is such as to confine the transmitted radiation to spectral energy of wavelength 546 millimicrons. Similarly in a third position the transmitted wavelength is 436 millimicrons.

In the fourth position a "Visual" filter is interposed. This filter is of such design as to reproduce the response of the eye when taken in combination with the spectral characteristics of the cupric chloride liquid filter, and the spectral sensitivity of the photomultiplier tube.

A fifth filter position labeled "3" interposes enough neutral density that the flux received by the phototube comes within the range of operation of the instrument in view of the finite range of adjustment of the lamp-intensity control. This permits black-and-white densities from 0 to 3 to be measured directly. The sixth filter position, labeled 6, uncovers the phototube completely and in this case when a specimen density of 3.0 is placed in the sample position the meter reading can be brought to zero thereby permitting black-and-white densities from 3 to 6 to be measured. Ordinarily, there is sufficient latitude of flux control to permit measurement of densities up to 7.5.

The spectral characteristics of the combined source-phototube-filter-receiver products for the different filter cylinder positions of recent production units are illustrated in Figs. 11 and 12. It is believed that the visual filter combination shown in Fig. 12 represents one of the best approximations to the response of the eye yet obtained with a phototube having a spectral response similar to the average *S-4* surface

Although at the present time there is no standard for color densitometry (either ASA or SMPE) nor even a recommended practice, a proposal has been made to the American Standards Association for their consideration for adoption as an American Standard. This proposal specifies that for the densitometry of three-layer monopack color film the measurements shall be made at the three wavelengths corresponding to the prominent mercury and cadmium lines of emission which fall at 436, 546, and 644 millimicrons. These wavelengths lie close to the spectral density peaks of the average commercial color film. Furthermore, there is a good reason to believe that any satisfactory three-color process would of necessity have absorption peaks falling close to those specified. Therefore, it was a design goal to provide narrow band isolation filters which coincided in peak transmission with the proposed standard.

In Figures 11 and 12 the maximum log reciprocal (relative response) for each of the three blue, green, and red filters has been adjusted to zero. Actually, the *minimum* filter density, in the case of the blue filter, is approximately 4.0 at 436 millimicrons and since this

is virtually monochromatic, less than 1 part of 10,000,000 of the total energy of the initial beam is ultimately received by the phototube. It is somewhat difficult to design a satisfactory red-filter combination in spite of the greater relative energy emission of the tungsten lamp,

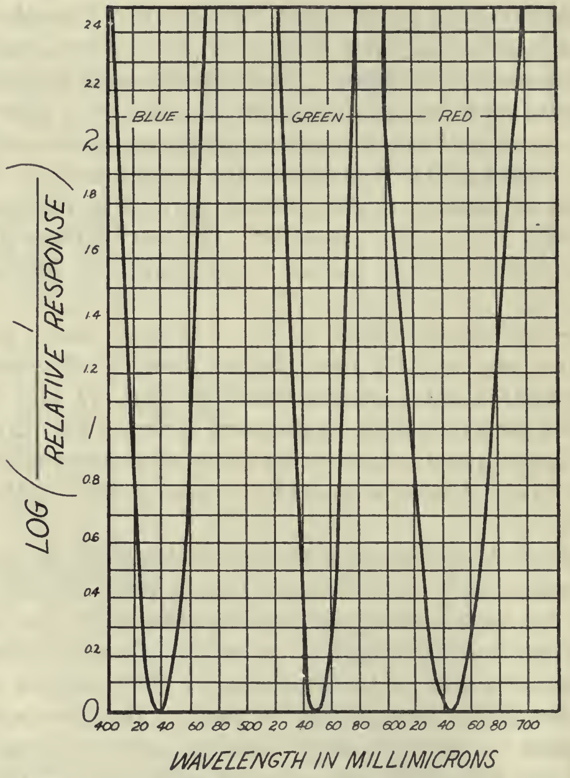

Fig. 11—Log (reciprocal relative response) versus wavelength for the three-color filters used for transmission measurements in the Ansco Color densitometer. The wavelengths corresponding to peak transmission coincide with those of a proposal made to ASA for color densitometry.

because the phototube response is relatively very feeble at wavelengths greater than 600 millimicrons. Although somewhat broader in its transmission band than the rest, the red-filter combination is sufficiently narrow for most practical sensitometric purposes.

The spectral characteristics of the combined system, when the filter control is put in the "3" and "6" positions are such as to meet the

requirements for measuring American Standard Density Type P-2b It is a simple matter to remove the cover plate of the measuring arm and substitute other gelatin filters for those originally provided, should this be desired.

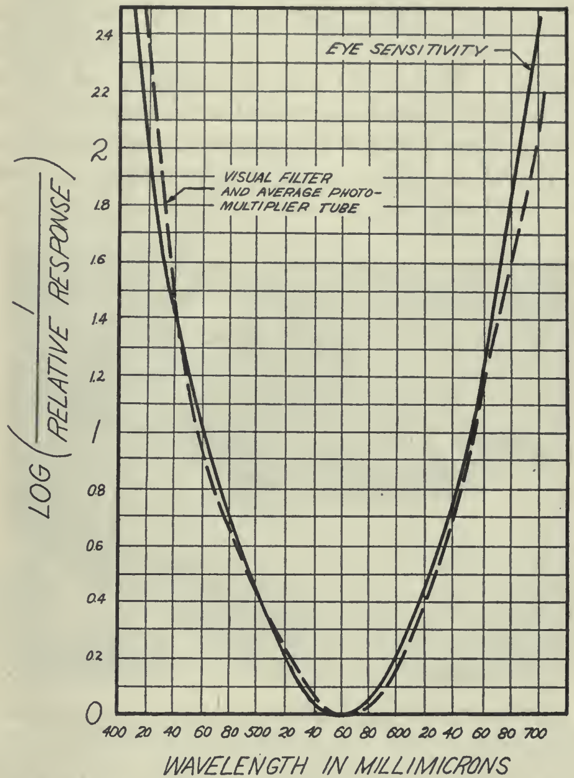

Fig. 12—Log (relative response) versus wavelength for the "visual" filter used in the Ansco Color densitometer, shown in comparison with the response curve of the eye.

The lamp voltage is controlled by a variable solenoid inductance and provides the required latitude of flux density. The arrangement permits smooth lamp operation of practically unlimited life.

Application and Performance

Fig. 13 is a photograph of the complete instrument. In use, the operator turns the instrument on with the rotary switch located at

the left of the measuring arm and after allowing a few minutes for the initial warm-up makes the zero adjustment with the filter selector and compensating circuit controls in their appropriate positions. The sensitivity control, located at the right of the measuring arm, is then adjusted so that a calibrated reference-density specimen gives a reading in agreement with its assigned value. The instrument may then be used for the corresponding position of the "Color—Black-and-White" switch, it being only necessary to check the zero and sensitivity-control adjustment occasionally during warm-up. It is recommended that in cases where the instrument is used daily, it be left in continuous operation. This minimizes the frequency at which zero and sensitivity checks are necessary. Since all of the components

Fig. 13—External view of the Ansco Color densitometer.

are operated at well below their nominal capacity, they have a long useful life.

For reading color densities, with the "Color—Black-and-White" selector switch in the "Color" position, the operator simply adjusts the sensitivity to give a meter reading which is in agreement with the preassigned reference density value using the green filter, then proceeds to take routine readings. In the case of black-and-white measurements a similar check reading is made with the selector set switch in the "black-and-white" position and with the filter selector at "3" densities between 0.0 and 3.0 are then read directly. Densities between 3.0 and 6.0 may be read by inserting sufficient sample den-

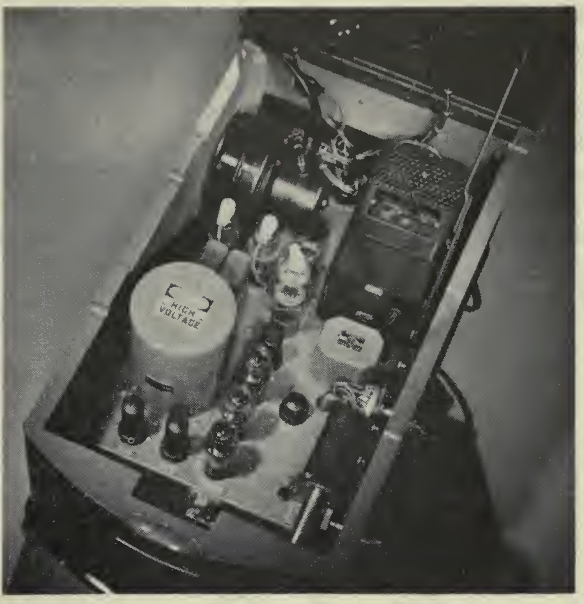

Fig. 14—Instrument chassis—showing high-voltage transformer, control and rectifier tubes, lamp-voltage stabilizer, and zero-adjustment solenoid.

Fig. 15—Liquid-density attachment in use.

sity in the beam to bring the meter reading to 3.0, while the instrument is adjusted to read correctly from 0.0 to 3.0, then setting the filter control to 6 and readjusting the zero control to bring the pointer to 0.0 setting.

The instrument chassis can be seen in Fig. 14. No specially selected, calibrated, or aged tubes are used. The response characteristics of virtually any photomultiplier tube can be compensated to give results which are in agreement with density values marked on the uniformly calibrated meter scale, by simple adjustment of the compensating circuit. The inherent stability of operation is assured by the basic feedback circuit.

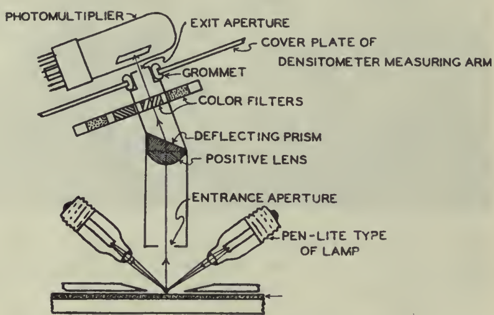

Fig. 16—Optical system of reflection attachment for color densitometer.

Of course the measuring arm can be used as an exploring element by removing the pivot shaft from the base of the arm. The inherent sensitivity of the instrument is between 1.0 and 0.1 microlumen at a density reading of 3.0.

Densities up to 4.0 have been measured through a circular aperture only 0.001 inch in diameter by replacing the standard aperture plate with one having a smaller size opening. An attachment has been designed for measuring the density of liquids and is shown in Fig. 15.

Another attachment permits the reflection densities of solid substances to be measured in color and in black and white. The optical system is shown in Fig. 16. Stray light is eliminated to such an extent that for a typical unit less than one part in 1000 of the specularly reflected component of the incident beam affects the phototube when a first surface mirror is placed in the specimen position.

Fig. 17 shows the head itself and Fig. 18 shows the head in actual use. Fig. 19 shows the spectral-energy-response product curves for the three-color filters used in the reflection head.

Fig. 17—Reflection attachment for color densitometer.

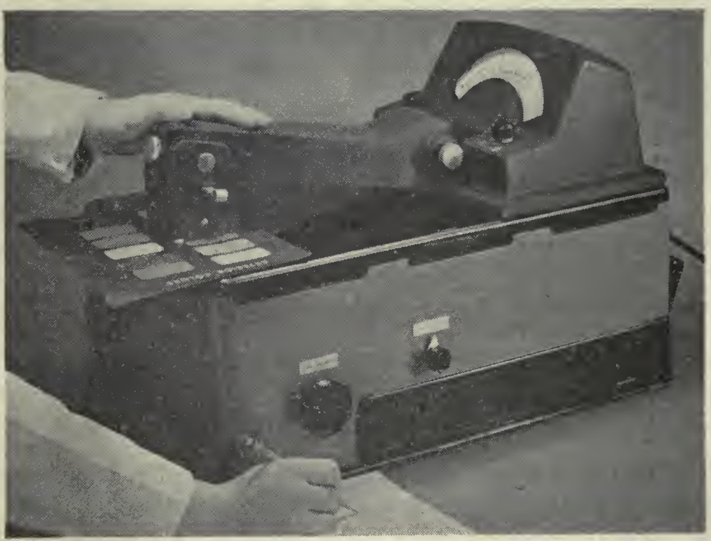

Fig. 18—Reflection attachment for color densitometer in use.

One of the most attractive applications of the instrument is for automatic recording. Since the densitometer is unique in having an

electrical output which is uniform in density it can be attached directly to any standard ink recorder such as the Brown high-speed automatic potentiometer and used as a linear automatic recording densitometer.

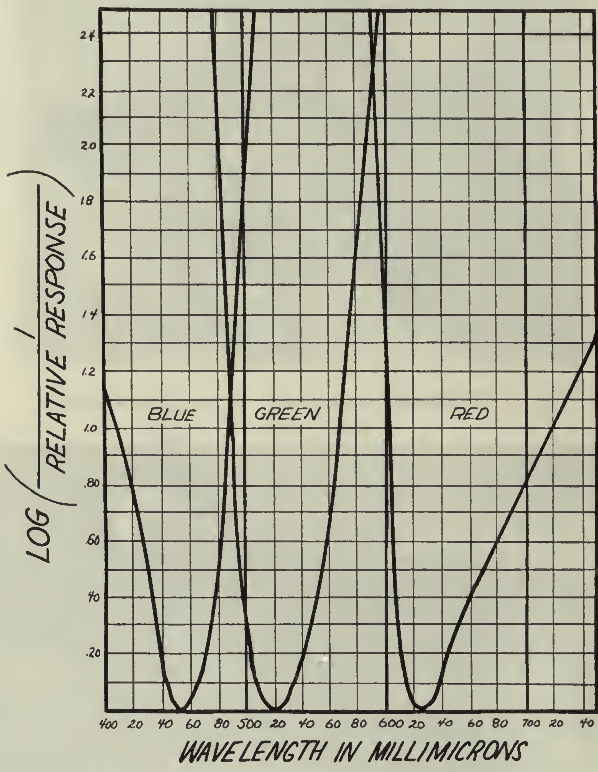

Fig. 19—Log (reciprocal relative response product) curves for filters used in reflection attachment.

Wherever large numbers of sensitometric or similar strips are to be read the use of the automatic recording combination makes analysis faster, more convenient, more fully objective, and therefore more nearly free from error.

Automatic recording systems require "smooth" modulation strips for satisfactory operation. In the case of the Eastman Type II-b sensitometer these may be obtained by masking the steps of the ex-

posing drum with a smooth cover plate* or by using the sensitometer as is and inserting a "repeating" step wedge.†

Fig. 20 shows the instrument with a simple film-drive unit attached to a linear high-speed recorder. Fig. 21 shows a series of three traces for a color-film sensitometric strip. Each trace is recorded in the color corresponding to the color of light at which the measurement was made. Further application of the automatic recording system in the motion picture field will be reported at a later date.

The speed of response is entirely dependent on the characteristics of the indicator since the response time of the photomultiplier tube

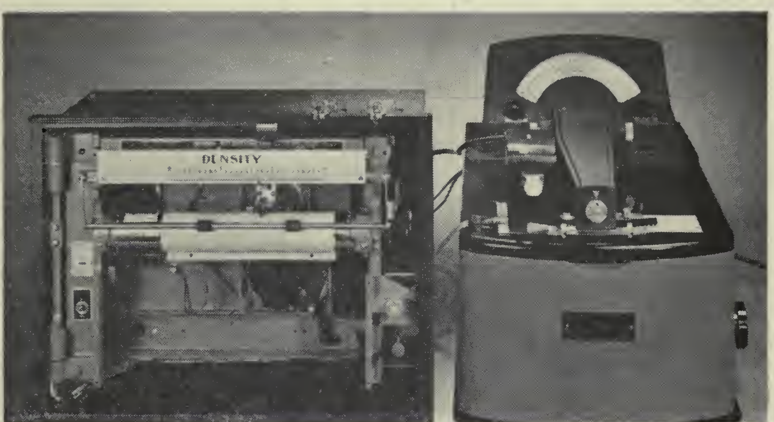

Fig. 20—Color densitometer used in conjunction with Brown high-speed ink recorder for automatically recording color densities. Color of the ink used in making the individual traces corresponds to the color of the isolation filter.

and associated control-tube circuits is of the order of magnitude of milliseconds. Therefore, in automatic recording, the speed of response is limited solely by that of the recorder.

ACKNOWLEDGMENTS

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* United States Patent, 2,406,702, H. W. Moreall, Jr., 8/27/46.
† United States Patent, 2,457,746, M. H. Sweet, 12/28/48.

larly to Mr. Karl Greif for his assistance and many excellent suggestions which contributed materially toward making it a better instrument.

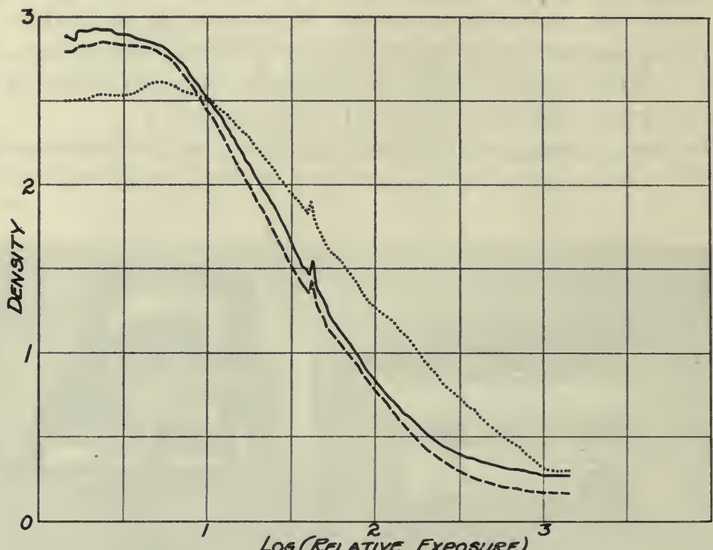

Fig. 21—A direct trace of an actual recording of a color-film strip made using the equipment shown in Fig. 20 (in the original record each curve is drawn with an ink whose color corresponds to that of the isolation filters). The solid line was traced from the blue-ink curve, the broken line from green-ink, and the dotted line from red-ink. Total time for recording three complete traces was slightly less than two minutes (including loading and unloading sensitometric strip and graph sheet). The "pips" in the three curves correspond to a fiducial line exposed on the sensitometric strip itself in order to indicate the alignment of the three traces.

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Color Measurement of Motion Picture Screen Illumination

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Summary—In comparing the color quality of motion picture projector light sources, it is of little value to judge bare screen colors, with no film in the gate. A complete specification of the spectral distribution of the radiant energy is required. Short-cut methods of evaluating and specifying this important property are described, involving the use of red, green, and blue filters to determine the ICI trichromatic coefficients, and, from these, the color temperature. A method of combining direct color measurements on the carbon arc crater from various angles of view to yield the screen color in any optical system of interest is also described.

The colors appearing on the motion picture screen when color film is in the projector gate are the combined result of the spectral distribution of the radiant energy from the light source and the spectral transmittance of the film. Useful color comparisons of light sources in this service thus require a much more accurate knowledge of their spectral qualities than can be derived from the visual examination of bare screens, with no film in the gate. For example, the white color of a bare screen illuminated by an equal-energy source, with identical radiant intensity at all wavelengths, can be exactly matched, visually, by a hypothetical light source consisting of nothing more than approximately equal parts of sodium vapor yellow (5890 A) and a monochromatic blue (4860 A). Although there would be no visual way of telling from the identically-matched bare screens, it is obvious that color film would look very much better with the equal-energy source.

The real test of a light source in color film projection is thus a visual evaluation of the picture colors finally produced on the screen. Independent evaluation of the light source itself is possible only in terms of the complete specification of the spectral distribution of the radiant energy as related to the transmittance of the film. Such a specification is very useful in many colorimetric calculations, such as those directed toward a determination of what a so-called standard observer[1] would see in any given case. In a previous paper,[2] data

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of this sort were presented for a number of typical projector combinations, and it was pointed out that a close correspondence exists between the spectral distribution of carbon-arc screen light and that of a black-body, heated to the closest color match. As applied to the specification of carbon-arc screen light, therefore, the so-called color temperature of that light has useful meaning in defining in simple terms a spectral distribution of sufficient accuracy for most colorimetric work.

The determination of screen-light color temperature through the measurement of the spectral distribution of this light is, however, a tedious process, so that a simpler means of color temperature determination is desirable. Here we have found the photocell-filter combination suggested by R. S. Hunter[3] of value, in which comparative photocell readings are taken with specially selected red, green, and blue filters. These readings specify the ICI (International Commission on Illumination) trichromatic coefficients, x, y, and z,[1] of the screen color in question, and these may be compared with the corresponding coefficients of black-bodies at various temperatures to find the one most nearly a match. We have confirmed Hunter's finding that it is necessary to calibrate the photocell-filter system directly against light sources of known color quality, similar to those to be measured. For instance, when our cell and filters are calibrated against an incandescent tungsten standard of 2848 K (degrees Kelvin) color temperature, we find that the red filter readings require the addition of an 8 per cent correction to give good values in the 5000–6000 K range of carbon-arc sources.

Figure 1 shows the apparatus employed in these three-color screen light measurements. A photocell with a plain glass window is mounted on a frame, with provision to slide any one of three color filters in front of it. The chain drive shown permits convenient remote operation of the filter slide when the assembly is mounted on top of a pole, in the center of a full-size motion picture screen. From the relative readings obtained with these three filters, the trichromatic coefficients, x, y and z, of the screen-light color are obtained. These in turn are referred to a chart similar to that shown as Fig. 2, which is an expanded section of the ICI color diagram including a portion of the black-body locus, and with iso-temperature lines and uniform chromaticity ellipses calculated after the method proposed by Dr. B. D. Judd of the Bureau of Standards.[4]

As an example, the screen color with the new Hitex[5] 13.6 mm carbon

at 170 amp is plotted at the point A. Following the slope of adjacent iso-temperature lines to the black-body locus gives a color temperature of 6250 K, directly indicated by the scale drawn along the locus. The divisions of this scale are drawn at the halfway points between the indicated temperatures (*e.g.*, at 6225 and 6275, on each side of 6250 K), extrapolations from color points to any point between two divisions being assigned the same color temperature. Our experience in duplicating optical setups and the associated measurements indicates that no greater accuracy, applicable to all commercial

Fig. 1. Photocell-Color Filter Assembly; used to determine the ICI trichromatic coefficients of screen light.

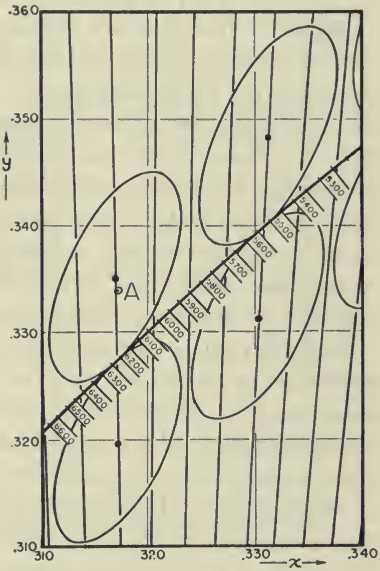

Fig. 2. Section of the ICI Chromaticity Diagram; showing the black-body locus in the range of carbon-arc screen colors, together with the iso-temperature lines and the equal-color-difference ellipses used to evaluate the departure of a given screen color point from the black-body locus.

systems of the type described, is justified, although the mathematics with a given set of data do permit a much closer specification.

The chart of Fig. 2 may also be employed to give a measure of the difference between a screen color of interest, *i.e.*, point A, and the nearest matching black-body color. According to Judd,[4] the ellipses of this chart define the locus of color points 10 units of least perceptible difference (LPD) removed from the color point in the center of the ellipse. Therefore, since the distance between point A and the black-body locus at 6250 K is 9/10 the nearest parallel ellipse radius, the Hitex carbon screen color is said to be 9 LPD from this black-

body color. Such information is useful in evaluating the validity of the color temperature nomenclature in any given case.

It is also of interest to know something of the chromatic nature of such a color difference. To determine this, the line joining the screen color point with the nearest black-body color is extrapolated to the spectrum locus, as in Fig. 3, to give an intercept B defining the spectral nature of the color difference. It is thus determined that the Hitex carbon screen color could be exactly matched by adding about 2 per cent of monochromatic green radiation of 5500 A wavelength to the color of a black-body at 6250 K.

Figure 3 also shows a number of other screen color points with various carbons and optical systems, showing in all cases a close grouping about the black-body locus. Of greater significance in evaluating the validity of the black-body designation, however, are the curves of Fig. 4. These show the complete spectral distribution of radiant energy for the Hitex carbon screen color, together with that of the 6250 K black-body, which most nearly matches it. The difference between the two curves, ordinate by ordinate between 4000 and 7000 A, averages only 3 per cent. For most visual studies, this order of accuracy would seem quite adequate.

Various proposals have been made[6,7] to simplify the foregoing procedure by measuring only two color components of the screen light, associating the color temperature with the ratio of these two readings. Depending upon the accuracy of the calibration, this can be made a quite satisfactory procedure for light sources similar to black-bodies in relative spectral distribution, but suffers from the limitation that the answer is always some exact color temperature, with no indication of the magnitude or chromatic nature of the departure from the black-body locus.

Further, it should be borne in mind that the significance of these findings is confined to the visual spectrum, 4000 to 7000 A. From other studies, we know that the infrared radiation of carbon arcs is much less than that of the visually-matched black-body. Also, the ultraviolet radiation is in general much higher for arcs than for visually equivalent black-bodies, although this is modified in marked degree by the absorption of the glass parts of the optics. Thus, while color temperature designations are useful in studies involving motion picture projection where the human eye is the receiving instrument, they must be used with considerably greater caution in other applications, such as photography, for instance, where the recording sensi-

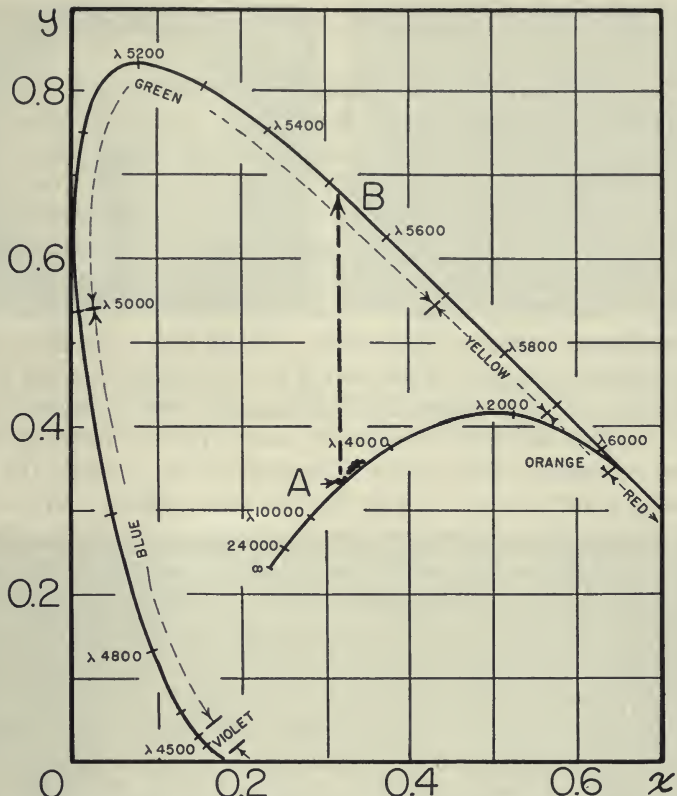

Fig. 3. ICI Chromaticity Diagram; showing typical screen color points with relation to the black-body locus and the locus of spectrum colors.

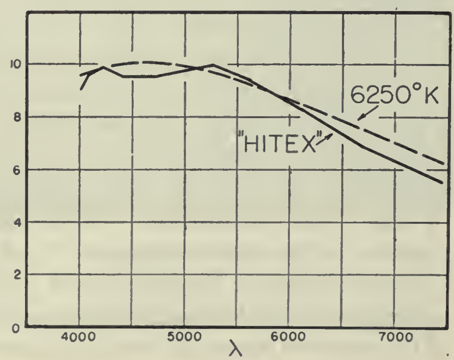

Fig. 4. Spectral Distribution of Radiant Energy; comparing the screen color with the new 13.6-mm Hitex super-high-intensity carbon at 170 amp with that of a black-body at 6250 K.

tivities vary with wavelength in a manner widely different from that of the eye.

So far, this paper has been concerned with the evaluation of the final screen color, without regard to its origin. It is also of interest to study the characteristics of the source and of the optics which determine this end result. In this connection, it has been pointed out by Jones,[8] among others, that motion picture screen illumination is, in fact, an overlay of many crater images of varying magnification, elliptical foreshortening and orientation, as these things are determined by the different angles with which the source is viewed by the elemental areas of the optical system. In this way, color and brightness variations existing at the source are smoothed over the screen to give a much higher order of brightness and color uniformity than exists over any one direct view of the source itself. This highly important averaging effect can be demonstrated by masking the light collecting element in such a way that the screen light at any instant is confined to that delivered by a single elemental area of the collector element. If, then, this mask is moved about to explore the surface of the collector, the corresponding array of screen light distributions will give a sequence, one at a time, of the individual images in the complex overlay which constitutes the screen illumination. However, in a motion picture projection lamp, it is quite difficult to move such a masking device conveniently about inside the lamp housing while the projector is in operation. Fortunately, a completely equivalent effect can be secured much more simply, entirely outside the projector housing, by locating a pinhole in the light beam at a suitable location in front of the projection lens. Just as a lens of 5 in. focal length will image an aperture plane 5.01 in. distant at a screen 100 ft away, so will this same lens image the elliptical mirror in a Suprex arc lamp, for instance, in a plane a little less than 6 in. in front of the focal point of the lens. Such a mirror image is shown by Fig. 5. A pinhole placed in this image plane will thus limit the screen light to that originating from the small mirror element imaged in the pinhole just as effectively as if all but this area of the mirror itself had been blackened. In order to utilize this effect, the apparatus illustrated by Fig. 6 was constructed. This is adapted to locate a pinhole anywhere over the mirror image of Fig. 5.

Figure 7 shows a typical view of the screen light so obtained, from a mirror segment looking at the crater from a 65° angle. The outline of the aperture image has been emphasized on the negative from which

Fig. 5. Image of the Light-Collecting Mirror of a Typical Suprex Carbon Arc Lamp; formed by the motion picture projection lens in a plane close to the front surface of this lens.

Fig. 6. Pin-Hole Locating Device; mounted in the mirror image plane of Fig. 5, and adapted to restrict the screen light to that originating from mirror segment imaged in the pin-hole.

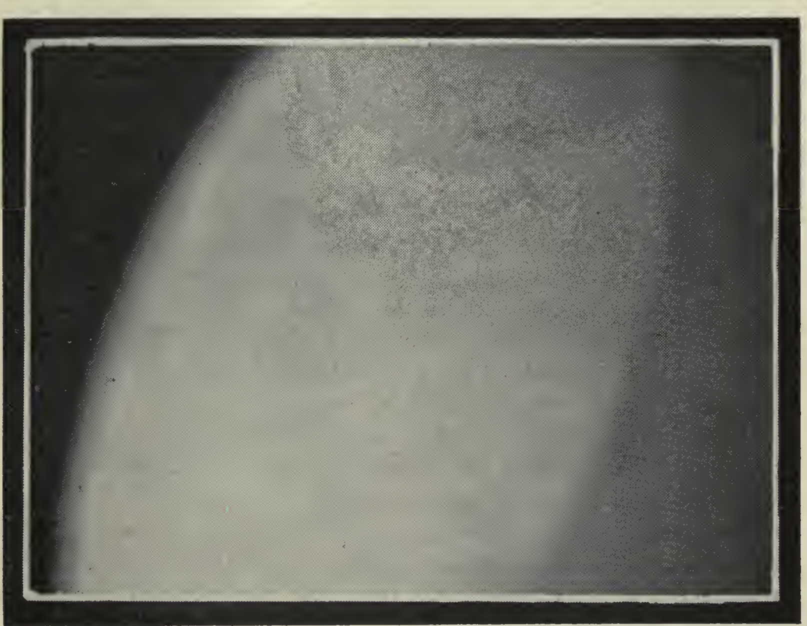

Fig. 7. Screen Light Contribution of an Elemental Mirror Area; viewing the carbon arc crater from an angle of 65°, and showing the crater imaged elliptically in the center, with the flame light ahead of it to the right; the projection lens fails to pass the shell light behind the crater, which would otherwise have been imaged in the dark section at the left.

this print was made. The elliptically bounded section in the center of the screen is the image of the high intensity crater, which, from this angle of view, does not completely fill the aperture. To the right, the less brilliant light from the arc flame in front of the crater is imaged. The completely dark section to the left indicates that portion of the aperture which receives no usable illumination from the mirror segment under study. In this particular case, light originating from the positive carbon shell on the side of the carbon nearest this mirror segment is reflected through the far side of the film aperture at an angle outside the cone accepted by the projection lens.

The result of summing the illumination of Fig. 7 with that from all the other mirror segments is a rosette-like overlay, with crater images at all possible angles, and with the dim and the dark sections distributed uniformly over 360° around the center of the screen. The very important function of the optical system in thus averaging the nonuniformities of the individual mirror contributions, like Fig. 7, to give the uniformly white screen which characterizes a well-aligned projection system is thus apparent. At the same time, the nonuniformities in color and intensity which result from careless optical alignment, putting the individual images like Fig. 7 off center on the gate to bring in variable amounts of shell and crater light, can be readily visualized.

With the condenser light-collecting optics which are commonly employed with larger carbons at higher currents, the same fundamental considerations apply. The incomplete aperture coverage of Fig. 7 is avoided, however, by the use of a smaller light-collecting angle with a corresponding reduction in the ellipticity of the crater images on the aperture. This advantage is counteracted to some extent by the spherical aberration of the condensers, which images the angular views of the crater somewhat off center on the aperture.

This breaking down of the screen light into its optical components suggests the reverse procedure, previously described by Jones,[8] of measuring the light distribution over the carbon-arc crater region from various angles of view, and then combining these, with proper weighting factors, to predict the projector aperture and screen illumination with any optical system of interest. Since Jones was interested only in evaluating light intensity, he used a conventional Viscor-filtered photocell in all his crater measurements. In the work described here, this procedure was extended to include the use of the clear-window photocell and the red, green, and blue filters used to

determine the ICI trichromatic coefficients of screen light. Thus instead of a single trace of brightness variation across a given crater image, three such traces are obtained, with each one of the three color filters in turn. Each one of these may then be treated as Jones did to give a summation of the corresponding color intensity over the aperture with any light-collecting system of interest.

Figure 8 shows a view of the crater image board, with a clear-window photocell in use. The color-filter slide shown in Fig. 1 is located in the beam near the crater, so that any one of the three filters may be put into the beam. The procedure at the image board is exactly the same as was previously described,[8] except that now three separate sets of intensity variation data are obtained, one with the red, one with the green, and one with the blue filter in the light beam.

Figure 9 shows such data for two angles of view of a typical carbon-arc crater. Through the application of the appropriate magnification ratio of the optical system for each angle, these color intensity variations may be transferred to the plane of the motion picture projector aperture and from there to the screen. Here the appropriate weighting and summation of these with similar data from other angles of view give a prediction of the screen-light color resulting from the total overlay of crater images on the screen.

In accumulating data with this system, a phenomenon was observed which is of some theoretical interest, and perhaps may have practical value in certain types of optical calculations as well. In correlating the color intensity distributions across the crater from several angles of view, an attempt was made to interpret these in terms of a single plane of origin which would produce cosine-law variations matching the observed behavior at various angles. No single plane could be found to satisfy this condition for all three colors, but it was found possible to secure somewhat better correlation with any one color. For instance, referring to Fig. 10, it was observed with the green radiation across the horizontal axis of the crater, that the point of maximum brightness appeared to originate from a point some finite distance inside the crater, 1.3 mm in the case described. Similar consideration of the blue and red components gave apparent origins 0.5 mm and 1.7 mm inside the crater, respectively. Measurements of this same phenomenon, made on several other types of carbons, gave different absolute values, but always in the same relative order. This is in accord with the concept that the coolest region in the crater is next the crater floor, where the vaporization temperature of carbon,

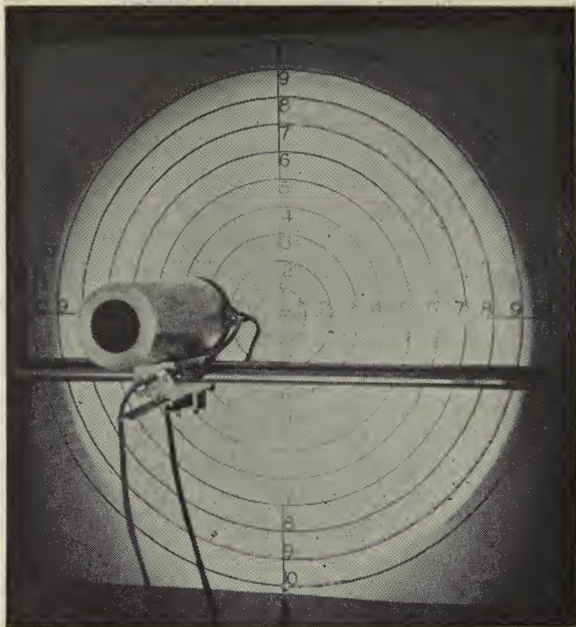

Fig. 8. Crater Image Board; adapted for tracing the red, green, and blue intensity distributions across the crater.

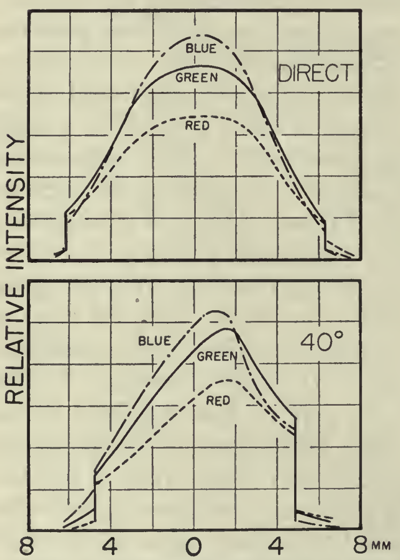

Fig. 9. Typical Crater Color Traces; viewed directly and from a 40° angle.

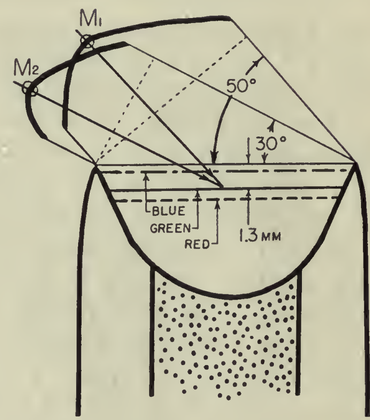

Fig. 10. Crater Color Intensity Distribution *versus* Angle of View; showing the apparent origin of the most intense green radiation at a point 1.3 mm inside the crater; similarly determined positions for the blue and the red radiations are also indicated.

ca. 3900 K, limits the maximum temperature to that value. As the distance from the crater floor increases, within the confines of the crater, so does the temperature of the crater gases. Such a hypothesis explains the occurrence of the maximum intensity for the lowest energy red radiation nearest the crater floor, and that of the highest energy blue radiation farther out in the crater cavity. In terms of screen illumination, these differences are of no practical consequence. They do, however, enhance our theoretical understanding of what goes on in the crater region, and, from that standpoint, contribute to the continued improvement of the high intensity carbon arc as a motion picture projector light source.

In conclusion, it should be re-emphasized that any useful specification of the color of motion picture screen illumination must give a measure of the spectral distribution of the radiant energy involved. Trichromatic coefficients and color temperature values are of interest only in so far as they give such information. With carbon arcs, close correspondence to the black-body type of continuous radiation, with substantial amounts of radiant energy at all wavelengths in the visual region, permits the effective use of this abbreviated nomenclature. It is this same uniformity of spectral distribution which assures the effective reproduction of natural color on the motion picture screen.

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Cinecolor Three-Color Process

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Summary—The basic chemical reactions, spectral characteristics of the dyes and types of machines utilized in the film processing are discussed in detail. The entire Cinecolor three-color process is described from the printing of negatives to the final inspection of the finished print.

The Cinecolor three-color process is a subtractive process whose application is found primarily in the theatrical and commercial fields where many copies from an original are required.

The three-color process is designed for, and depends upon, three-strip separation negatives for its printing medium. These negatives may be obtained from alternate or skip-frame techniques such as are employed in cartoon photography and three-strip beam-splitting cameras; or separations made from monopack films, such as Kodachrome or Anscocolor. Aside from the above, it is not the purpose of this paper to delve into the technique of producing negatives but rather to describe the print process.

Because of the years of experience which the company has had in the two-color field, the controls which have been developed, and economies of operation which have been effected, the three-color process was intentionally developed along the lines of the two-color system. In other words, the attempt was made to develop the three-color method, as much as was feasible, as an extension of the two-color process.

The positive raw stock utilized is the conventional and well-known duplitized film consisting of the usual base with color-blind positive emulsions impregnated with a water soluble yellow dye coated upon both sides of the base. It is of interest to note that this film has exceptionally good projection life, outlasting prints on single coated stock.

Printing

Assuming that three-strip separation negatives are available, the blue record will be referred to as the yellow printer, the green record as the magenta printer, and the red record as the cyan printer. The

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first step in the process is to print two of the records simultaneously onto opposite sides of the positive film. While it is not essential, the common practice is to use the cyan and magenta printers in this first operation. In the same operation, the sound track is printed to the side of the film which is subsequently to contain the cyan image. As a result, the positive raw stock reaches the process department having latent images of the magenta component on one side of the film and the cyan picture component and the sound track on the opposite side. Because of the necessity of maintaining these two picture images in perfect superposition or registration, step printers rather than continuous printers are utilized.

These printers, as illustrated in Fig. 1, have two lamp houses connected to the film gate by means of light tunnels. As can be seen from the illustration, the two separation negatives are brought down through the film gate with their image-containing gelatin coatings facing each other, with the positive film sandwiched in between. Before reaching the film gate one of the negatives, which has been previously edge-notched, passes through a conventional breaker box whose purpose it is to actuate a light-changing device at the instant the change of scene occurs in the printer aperture.

The Cinecolor printing machines utilize push-down pins located just above the aperture rather than the conventional pull-down pins which are usually present below the aperture. Because of this, the wear and tear on the perforations utilized for registration is minimized because, no matter how badly shrunk the negatives might be, the registration pins of the printers are caused to enter sprocket holes in the film which are no more than a small fraction of an inch away from the holes utilized for advancing the film. In this manner no punching can occur with the registration pins and, as a result, it is the rule, rather than the exception, that the steadiness and excellent image superposition of the five hundredth copy is identical with that of the first copy.

The light-change device employs a continuous loop of opaque leader stock which has punched in it holes of variable but predetermined size. This leader stock is advanced automatically by means of a solenoid-actuated sprocket which, in turn, is controlled by an electrical contact which occurs when the notch in one of the negatives referred to above reaches the breaker box. In other words, this might be referred to as a variable area type of light changer. As shown in Fig. 1, the film, after leaving the picture aperture, continues on down to where it is

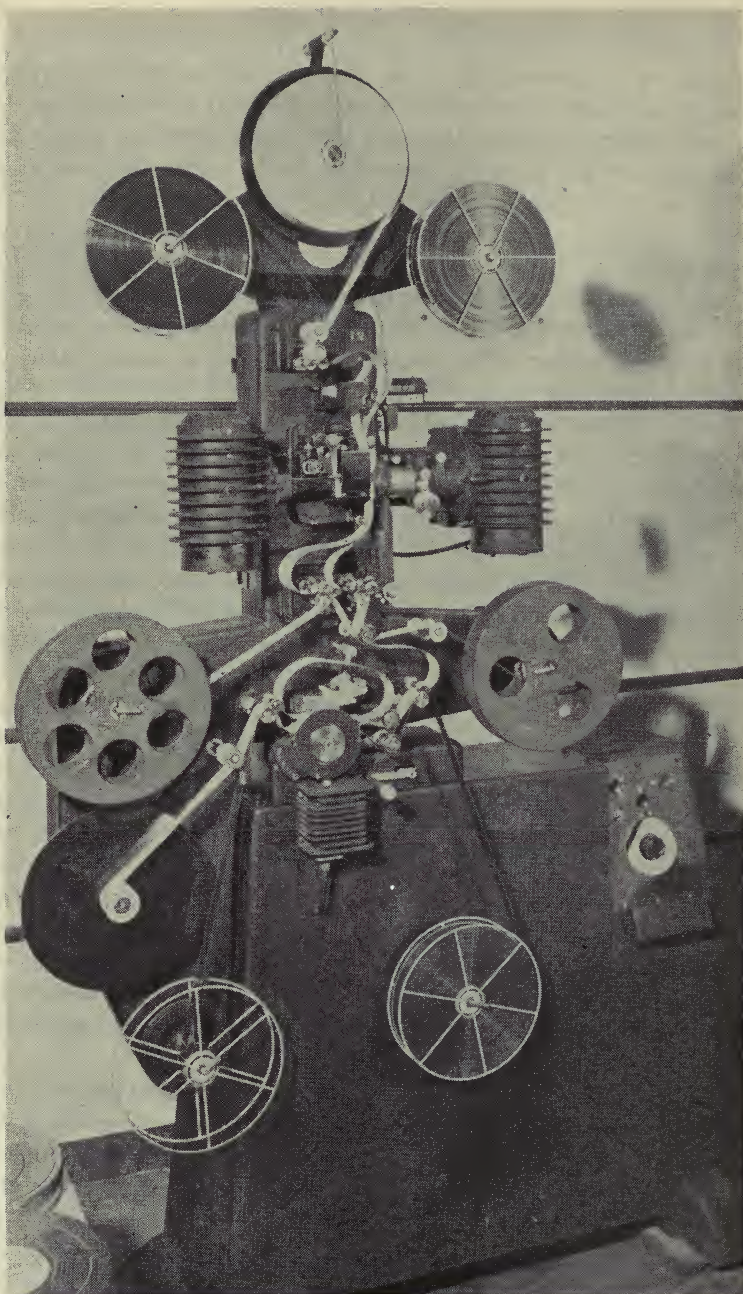

Fig. 1. Release printer.

met by the sound track negative and both of these films are passed over a continuously rotating conventional sound sprocket containing the typical sound aperture which is illuminated from a lamp house below.

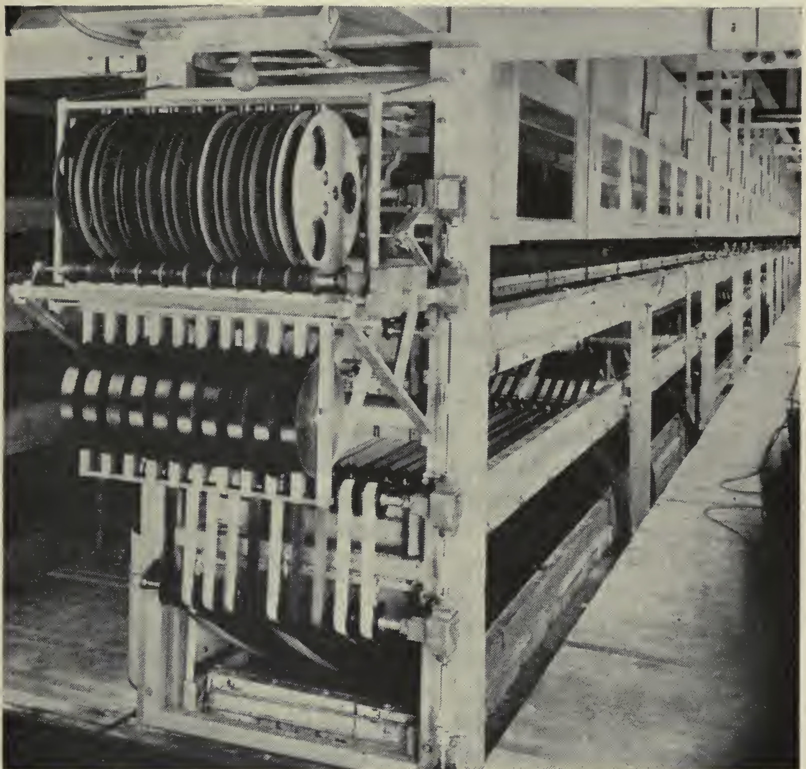

Fig. 2. Color process machine.

PROCESSING MACHINES

The present processing machines consist of three horizontal shallow troughs, one above the other, and wide enough to accommodate ten strands of film, as illustrated in Fig. 2. The immersion time in each solution and wash is held constant and the duration is controlled by the spacings between partitions or dams. The flow rates of the solu-

tions and washes, as well as temperatures, are held constant. The wash water utilized in the process is brought up from several deep wells, properly filtered and passed into the main distribution tank. It is extremely fortunate that the temperature of this well water remains quite constant throughout the year, varying between 64.5 F and 65.0 F.

Each of the ten strands of film on the processing machine, while operating at constant speed, is, nevertheless, independent of the others. In other words, each strand can be started or stopped independently at will. The linear speed of each strand is 12 ft per min, making a total output capacity for each machine of 120 ft per min.

As can be seen in Fig. 2, the rolls of printed film are loaded on a rack and the rotation of the rolls is facilitated by means of ball-bearing spindles which are slipped through the film roll hub and which, in turn, fit into a sloping slot in the rack. It should also be noted that the take-up reels for each strand are directly above the corresponding roll of film in the rack so that the entire operation of the machine can be handled from the loading end. The take-up reels are made of Bakelite and the variable speed take-up is accomplished very simply by having these reels rest upon two rapidly rotating Bakelite spools placed on adjacent and parallel-driven shafts.

The driving sprocket for each strand is just ahead of the take-up mechanism and on the same level. As a matter of fact, for each strand there are two driving sprockets on adjacent parallel-driven shafts and by means of idler rollers on a swivel bracket the film can be held down against either of the driving sprockets. One of these sprockets contains 35-mm teeth and the other sprocket has 16-mm teeth but spaced laterally the same as on the 35-mm sprocket. This makes it possible to operate any strand with 35-mm, 16-mm, or 8-mm film interspliced in any manner. This is due to the fact that, in the substandard field, Cinecolor utilizes 35-mm width film with multiple rows of either 16-mm or 8-mm perforations so that it becomes necessary only to flip the pivoted bracket when a splice between 35-mm film and either of the two substandard films appears at the driving mechanism. While it is perfectly possible to operate the machine with this single driving mechanism, it is the practice, however, to safeguard the machine operation with several friction booster drives at the two ends of the machine in order to prevent the possibility of strands snapping due to build up of tension.

As can be seen from the photograph in Fig. 2, the film enters the machine in the top trough and progresses down the entire length to the other end of the machine where it passes over the end and down into the middle trough, where it is then going in the opposite direction. When the film reaches the driving end of the machine, it passes over the end of the trough and down into the third or bottom layer, where it is then progressing in its original direction. When it reaches the far end of the machine again, it comes out of the bottom trough past a double set of air squeegees and then progresses up into the dry box which extends the entire length of the machine. The film then moves back toward the head end where it passes through the driving mechanism and onto the take-up reel.

This very brief description of the Cinecolor process machine applies to all of the machines utilized by Cinecolor in its positive processes, with one minor exception. The three-color process involves two stages. Because of the simplicity of the first stage, which requires only a few solutions, the length of the machine permits it to be operated at twice the speed of the other machines, and thus to supply two machines utilized for the second stage of the process. To be more explicit, each machine is in itself a complete unit with respect to the two-color process, but in the three-color process three machines will do the work or create the output equivalent to two machines in the former process.

FIRST PROCESSING STAGE

When the film first enters the machine it is immersed in a conventional developer where the sound track, cyan, and magenta images are developed into silver. After a thorough wash the film is then passed by an air squeegee which blows off the excess moisture from the magenta side of the film. From here it is laid cyan down onto a solution whose purpose is to convert the sound track and cyan images into a cyan pigment. While the chemical reactions involved in this step of the toning operations are manifold and somewhat complicated, they can be illustrated in rather simple terms by the following equations:

$$\underline{4\,Ag} + 4\,K_3[Fe(CN)_6] \rightarrow \underline{Ag_4[Fe(CN)_6]} + 3\,K_4[Fe(CN)_6] \quad (1)$$

$$2\,Fe_2(SO_4)_3 + 3\,K_4[Fe(CN)_6] \rightarrow \underline{Fe_4[Fe(CN)_6]_3} + 6\,K_2SO_4 \quad (2)$$

Equations (1) and (2) may be combined to show the complete reaction as follows:

$$\underline{4\ Ag} + 2\ Fe_2(SO_4)_3 + 4\ K_3[Fe(CN)_6] \rightarrow \underline{Ag_4[Fe(CN)_6]} + \underline{Fe_4[Fe(CN)_6]_3} + 6\ K_2SO_4 \quad (3)$$

The above equations indicate that the reaction takes place primarily between the silver of the image, potassium ferricyanide, and a ferric salt, and that the end products of the reaction consist of silver ferrocyanide, ferric ferrocyanide (Prussian blue) and potassium sulfate.

In addition to these reactive agents the toning solution of course contains other materials which, because of ionization equilibria and the formation of complex ions, can control the availability of the reactive ions and consequently the quantity and character of the Prussian blue deposit which is formed. It is perfectly possible to control contrast and the degree of dispersion of the ferric ferrocyanide deposit by varying quantitatively and qualitatively the composition of the toning solution. It is possible to form a coarse grainy agglomeration which produces bad grainy effects on the screen as well as the destruction of resolution and definition, or it is possible to produce a colloidally dispersed deposit which is highly transparent, free from grain, and having high resolution characteristics. It is also possible to go beyond this point and produce such a high degree of dispersion that bleeding takes place, causing once again the loss of resolution. Once all the factors are known and properly controlled, it is a simple matter to form a cyan image which has excellent grain and resolution characteristics. In addition to this, the spectral quality of this type of image is good from the standpoint of three-color reproduction, as may be seen by reference to Fig. 3. A more complete discussion of the spectral characteristics of this image will be given later.

It will also be noted from the above equations that the silver which forms the original cyan image has at this stage of the process been converted to an insoluble silver salt, namely, silver ferrocyanide, which salt is both light insensitive and spontaneously developable if brought into contact with a developing solution.

When the cyan image has been completely converted in the solution referred to above, the film then passes into a wash where the unreacted toning solution is completely removed from the film, after which the film is immersed in another solution whose purpose is to

convert the silver ferrocyanide to silver bromide. At this stage the silver of the original cyan image is in the form, namely, silver bromide, where it was prior to the printing operations, with the exception that the original silver bromide crystalline structure has been destroyed. This reformed silver bromide is neither subject to spontaneous development nor is it particularly light sensitive.

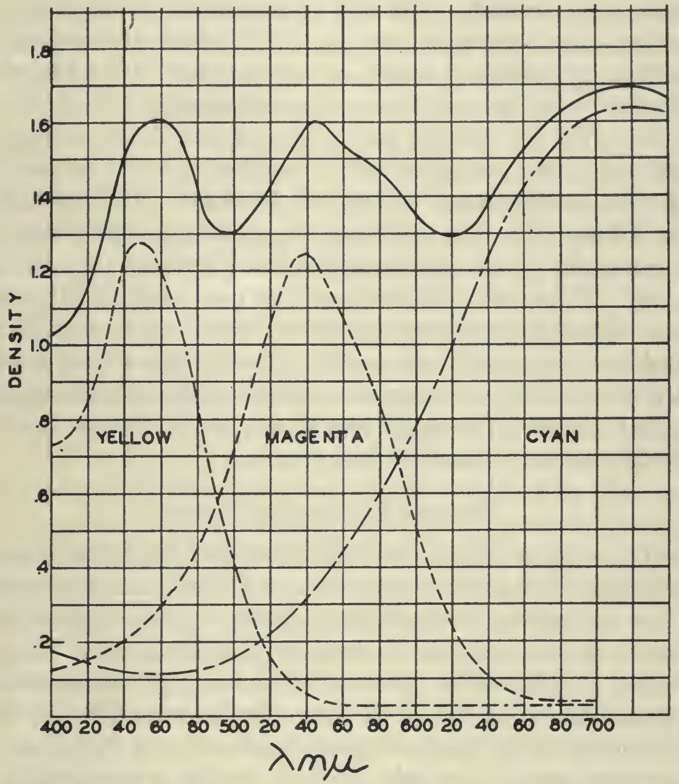

Fig. 3. Spectral-density characteristics of yellow, magenta, and cyan components.

It is possible, however, by controlling the character of the ferric ferrocyanide deposit surrounding these particles of reformed silver bromide to produce a degree of photographic sensitivity which is higher than that of the original silver bromide grain which existed in the raw unprinted form. By controlling further the character of the ferric ferrocyanide deposit it is possible to vary the sensitivity of the

reformed silver bromide in such a manner that this sensitivity is increased in direct proportion to the decrease in exposure brought about by the masking effect of the ferric ferrocyanide image. In other words, if one were to flash expose the film containing a cyan image the amount of latent image present in every part of the picture would be constant and this constant image could be brought up into silver by subsequent development just the same as though there were no cyan image present. This is an important consideration in view of the fact that later on in the process it is desirable and necessary to produce an additional image on the cyan side of the film without interference from the cyan image already present.

Upon leaving the solution last mentioned, the film is washed again, properly hardened, and given a final wash before it enters the dry box and is subsequently removed from the machine. The carefully controlled drying operation produces no appreciable shrinkage in the film because of the protection afforded the base by the coatings on each side. When the film comes off this first machine it has on one side an unfixed photographic emulsion containing a silver image of the magenta component and on the opposite side a cyan image imbedded in a complete photographic emulsion whose characteristics are such that the effective sensitivity of the entire surface is constant irrespective of the presence of that image.

SECOND PROCESSING STAGE

The next step in the process is the printing of the yellow component through the yellow printer negative. At present, this printing operation is accomplished on machines similar to those described above. When this operational step is completed the film is ready for its final processing. It should be remembered that the yellow dye with which the emulsions of the film were originally impregnated was leached out of the film in the first developing stage so that in the second printing operation some of the light to which the film is sensitive has penetrated through to the opposite side. In order to overcome this deleterious effect, the film is floated on the developer, the first solution of the second processing stage. This brings up the yellow component in silver on the cyan side of the film and the portion of the image which has penetrated through to the opposite side is allowed to die as a latent image.

It should be noted at this point that the floating operations involved in this process present no problems due to the fact that it is possible

to maintain high surface tension characteristics in the corresponding solutions. It is only on rare occasions that any trouble is encountered and this is due usually to raw stock defects. After leaving the developer, the film is washed and then proceeds into a hypo solution where the undeveloped silver bromide is dissolved and removed from both sides of the film. Following this, the film is again washed. Next in the process a bleach or oxidizing solution is used to convert the silver in the yellow and magenta component images to a dye mordant. Like the cyan toning step, this one involves a group of somewhat complicated chemical reactions which can be condensed and stated quite simply in the following equation:

$$\underline{2\,Ag} + I_2 \rightarrow \underline{2\,AgI} \tag{4}$$

As can be seen from this Equation (4), the bleaching solution contains iodine as a principal reactant, which combines with the silver of the image to form an insoluble silver iodide image that has the property of absorbing basic dyes. As in the case of the cyan toning operation, by controlling the concentrations of several of the constituents in this bleaching bath the degree of agglomeration or dispersion of the silver iodide deposit can be varied at will and controlled. It is quite evident that if the deposit is coarse the final image will have a high degree of opacity. This is due to the mordant itself and to low color saturation, not only because of the neutral component introduced by the mordant, but also because of the low saturation of the image with dye due to a high volume-to-surface ratio of the silver iodide particles.

On the other hand, the mordant image can be made so highly transparent that it is hardly visible prior to the dyeing operation, and, since the deposit consists of extremely small particles and the surface-to-volume ratio is high, the amount of dye absorption is very much greater. In this case, with the mordant having practically no opacity and with a high dye concentration in the image, the saturation of the color components is excellent. As in the cyan toning step, it is also possible to overshoot in this direction so that bleeding can occur, which of course destroys resolution.

When the bleaching step just referred to has been completed and the film has been washed, the magenta side of the film is blown off by air squeegees and the film is then floated on the yellow dye. Upon emerging from this solution, the film is washed again for a short period of time and is then passed by air squeegees to remove the excess moisture from the yellow side of the film in order that the magenta

side may be floated upon the magenta dye solution. After a final wash, the film is run through the dry box and emerges as a finished three-color print.

SPECTRAL CHARACTERISTICS

The characteristics of the Cinecolor three-color process may be best demonstrated by reference to Fig. 3 which shows the spectral density characteristics of the three components balanced to equal analytical densities.[1] It is of interest to note that the peak density of the yellow component occurs at wavelength 445 $m\mu$, which corresponds closely to wavelength 440 $m\mu$, which is commonly weighted because of the spectral sensitivity of the human eye, and that the peak density of the magenta component corresponds to 540 $m\mu$, which is also weighted for the same reason.

In the case of the cyan component, however, the density continues to rise beyond the weighted wavelength of 640 $m\mu$ into the infrared. This characteristic is responsible for the high fidelity reproduction obtainable with Prussian blue sound tracks when used in conjunction with the caesium photocell whose peak sensitivity is in the infrared. Still concentrating on the cyan component, it will be noted that the density at 540 $m\mu$ is slightly higher than that at 440 $m\mu$, which is the worst defect in the entire process. The degree of imbalance at these two wavelengths, however, is negligible, as evidenced by the high fidelity of color reproduction in this system. The result to be expected from this small defect is a slight reduction in the brilliance of green objects in the picture. This, however, becomes somewhat advantageous with respect to the possibility of obtaining good sound reproduction utilizing the potassium S4 photoelectric cell in sound reproducers. The over-all peak sensitivity of this type of cell, when used with incandescent exciter lamps, occurs in the green portion of the spectrum and by actual tests it has been found that the Prussian blue sound track with a slight modification of print density or sound negative gamma is just as satisfactory with this as with the caesium type cell.

It can be said, therefore, that the cyan component of the Cinecolor three-color process, while not perfect, is satisfactory. In the case of the yellow and magenta components, it can be observed in Fig. 3 that these two are excellent. The high degree of spectral quality of these three components may be illustrated in a different manner, namely, by observing the fact that the integral densities[2] of the three

components at their corresponding weighted wavelengths are in almost perfect balance when the analytical densities of the three components are identical. In other words, as shown in Fig. 3, the analytical densities of the three components are adjusted to the value 1.45. At the same time the integral density of the yellow component at 440 mμ is 1.24, that of the magenta component at wavelength 540 mμ is 1.24, and that of the cyan component at wavelength 640 mμ is 1.23.

It may be of interest to state at this point that the conversion factors from densities, as read on the E.R.P.I. densitometers, to analytical densities are 1.20, 1.30, and 1.40 for the cyan, magenta, and yellow components, respectively, when read through the Kodak Wratten 29, 61N, and 49 filters. As a result of the excellent balance between the E.R.P.I. densities of the three components and also between the integral densities at the weighted wavelengths when the three components are adjusted to equal analytical densities, it is evident that the process is capable of reproducing very accurately colors as well as neutral values. For example, if it were required to photograph a scale of reds which would be composed of yellow and magenta on the color print, the dominant wavelength of the scale should remain constant throughout. If it were necessary to maintain, for example, a low yellow integral gamma in order to compensate for a small density peak in the blue portion of the spectrum resulting from an imperfect magenta component, then a scale of reds would appear either red in the low densities and magenta in the higher densities or red in the higher densities and orange in the low densities. In addition to this, if the same condition prevailed as stated in the previous sentence, it would be impossible to reproduce accurately a scale of yellow densities since the heavier yellow densities would be lacking in saturation or conversely the lower densities would be too high.

In order to obtain a system which is capable of giving excellent picture reproduction both as to neutral and colored objects, it is essential that the spectral density characteristics of all of the components be of such a nature that a simultaneous balance will occur not only between the analytical densities or gammas but also between the integral densities or gammas. At the same time, the conversion factors between analytical and integral density or gamma should be as close to unity as possible. It has already been noted above that the integral densities are in almost perfect balance for equal analytical densities

and the ratios between analytical and integral densities are 1.45:1.24, 1.45:1.24, and 1.45:1.23, for the yellow, magenta, and cyan components respectively. These ratios are approximately 1.17. Qualitatively it can be seen from the curves in Fig. 3 that there is very little density of the cyan and magenta components in the blue portion of the spectrum, very little density of the yellow and cyan components in the green portion of the spectrum, and very little density of the yellow and magenta components in the red portion of the spectrum. This makes for brilliance and high saturation of color, when desired.

The wavy neutral curve shown plotted above the spectral density curves in Fig. 3, when evaluated by means of the trichromatic coefficients[3] indicates that the neutrals should appear to be an excellent visual gray, and this fact is supported by actual screen tests. The trichromatic coefficients for a high intensity projection arc have been found to be: $x = 0.3408$ and $y = 0.3583$. Trichromatic coefficients for the arc as seen through the Cinecolor three-color neutral are: $x = 0.3533$ and $y = 0.3423$. Taking the point located by the trichromatic coefficients for the arc as the white-point, the dominant wavelength of the visual gray is 538 C millimicrons, and the purity 6.25 per cent—a most adequate neutral. It can readily be seen that these values can be plotted as a point very close to the center of the Maxwell curve.

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New Projection Lamp and Carbon-Feed Mechanism

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Summary—This paper describes a new carbon-arc projection lamp employing an electronic system to provide automatic control of the carbon positions. Each carbon-feed mechanism is separately driven by an alternating-current motor actuated by an electronic impulse generator. Feeding speed of the carbons is controlled by varying the resistances through the generator control circuits to adjust the number of impulses supplied per minute to the alternating-current motors according to the carbon-consumption rates. A polarized directional electromagnet controls the position and shape of the tail flame.

Theater motion picture projection requires a highly concentrated, high-intensity light source to give the greatly enlarged image sufficient screen brilliance. The carbon arc is the only light source so far developed capable of supplying the necessary screen illumination. In the past forty years or more this arc source has undergone many changes both in the lamp mechanisms and in the carbons themselves, with resultant marked improvement in the quantity and quality of the light produced.

In order to provide the constant screen light necessary to satisfactory projection, close control of the carbon positions is essential particularly in the reflector-type high-intensity carbon-arc lamp. The lamp must provide three main features: (1) The positive crater must be held in exact focus. (2) The carbons must be fed together at the same rate at which they are consumed. (3) A magnet must be provided to minimize the effects of the magnetic field set up by the direct-current supply to the arc and to stabilize the position of the arc tail flame.

In the direct-current arc, the rate of carbon consumption varies according to the type and diameter of the carbons used, the current at the arc and the length of the arc gap. Since the positive carbon is consumed at a much faster rate than is the negative carbon, conventional lamps employ two feed mechanisms, one driving the positive carbon carrier and the other, the negative. Usually the two carriers

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are propelled by feed screws driven from a single direct current motor through speed reduction gears, clutches, ratchets, and cams. The cam or ratchet mechanism provides a means of regulating the travel speed of the individual carriers, while a rheostat regulates the overall speed of the single driving motor.

In general, these motor-driven feeding mechanisms do not maintain the crater of the arc in correct focus for any considerable length of time, and, as the crater face of the positive carbon wanders from its exact focal point, the light on the screen changes in color and intensity. Further, these mechanisms do not maintain a constant arc length, slight changes in the arc current or voltage resulting in changes in the motor speed which cause the feed mechanism to run too fast or too slow. Manual adjustment of the speed of one feed mechanism is unsatisfactory since such adjustment also affects the speed of the other carbon-feed mechanism.

To overcome these difficulties a new lamp has been developed which uses a separate drive-and-feed mechanism for each of the carbon carriers. Each carrier is driven by a nearly constant speed alternating-current motor energized intermittently by pulses fed from independent impulse generators. Any desired feeding speed can be obtained merely by adjusting the number of impulses per minute fed to the motor, so that almost micrometer adjustment of speed can be obtained, making it possible to hold the arc gap constant and maintain the arc in exact optical focus with the reflector-and-lens system to suit any required consumption rate of either positive or negative carbon.

Fig. 1 shows the complete positive carbon carrier with the cover removed. Fig. 2 shows this carrier in alignment with the negative carbon carrier, also with cover removed, and illustrating the motor, motor reduction gear, worm screw, carrier with side clamp, and carbon clamp. The carbon holders are full-floating and self-aligning, and are provided with fixed-pressure spring-tension clamps. The negative carbon guide and holder is adjustable both vertically and horizontally and, generally, is positioned so that its center is in line with the bottom edge of the positive carbon crater. To strike the arc the carrier is brought forward by pushing in the handle at the end of the worm screw. After the arc is struck, the carrier springs back to provide the proper arc gap. The motor drives the worm shaft through a friction clutch. For manual adjustment of the carbon positions, the worm shaft is turned against the friction of the clutch.

In order to secure the desired precision in carbon-feed control, it was necessary to develop a very accurate electronic impulse generator for supplying the energizing impulses to the alternating-current feed motor, and to incorporate a means for readily varying the number of impulses per minute between the upper and lower speed requirements for feeding the carbon being consumed. This generator is energized

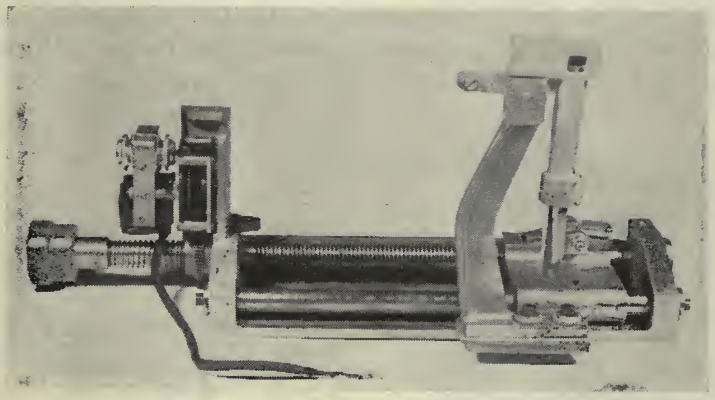

Fig. 1

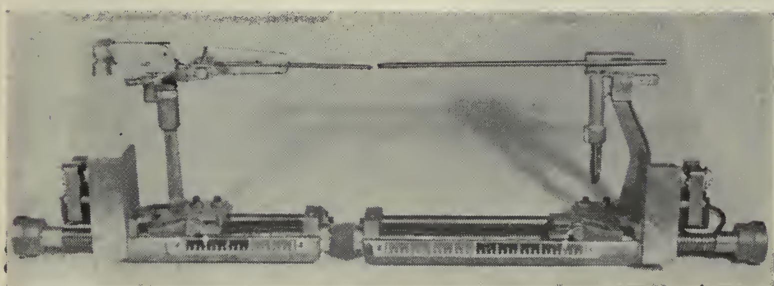

Fig. 2

from the 110-volt illuminating-current supply. It employs a small Thyratron tube, Type 2D21, in circuit with capacitors and resistors in such manner that the time cycle during which the current flows and ceases to flow may be regulated at will, simply by increasing or decreasing the amount of resistance in the control circuit. By merely turning the knob of the variable resistor clockwise or counterclockwise, the number of impulses from the impulse generator will be

increased or decreased. The impulse generator delivers its impulses to the actuating coil of a relay which by the opening and closing of its contacts intermittently connects the alternating-current motor with the 110-volt alternating-current supply. Any arc-voltage change does not alter the feeding speed as is the case when a direct-current motor is used, because the alternating-current motor is actuated from an entirely independent circuit. Thus the actuation of the alternating-current motor and associated feed mechanism can be controlled perfectly and accurately in order to feed the carbon forward at an exact rate. By the use of one of these impulse generators for

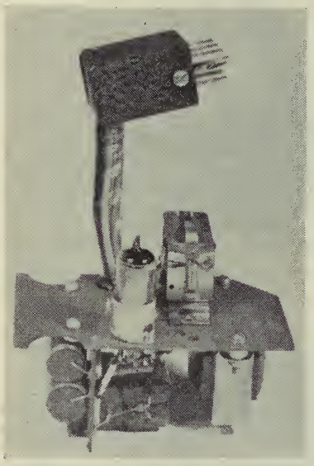

Fig. 3

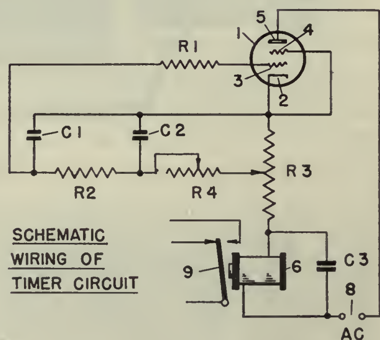

Fig. 4

operation of the negative-carbon feeding mechanism and another for the positive-carbon feeding mechanism, a separate and accurate control of each is obtained.

Fig. 3 is a view of one of the electronic timers showing the Thyratron tube, transformer, capacitors, and resistors in circuit, the relay for opening and closing the motor circuit, and the connector plug, which automatically makes all electrical connections.

Fig. 4 is a schematic circuit of the electronic impulse generator and Fig. 5 is a schematic of the electrical circuits employed in the projection lamp.

Fig. 6 shows the relay which prevents the lamp feeding mechanism from operating when there is no arc between the carbons. This is

accomplished by using a series coil in the arc-supply circuit to actuate the relay, the contacts of which open and close the motor circuits.

In all arc lamps of this type a magnetic field is set up from the direct-current supply to the carbons which has a marked effect on the burning characteristics of the arc itself. Heretofore, it has been the

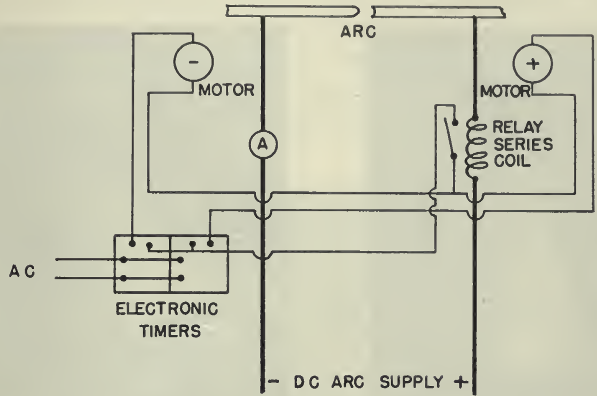

Fig. 5

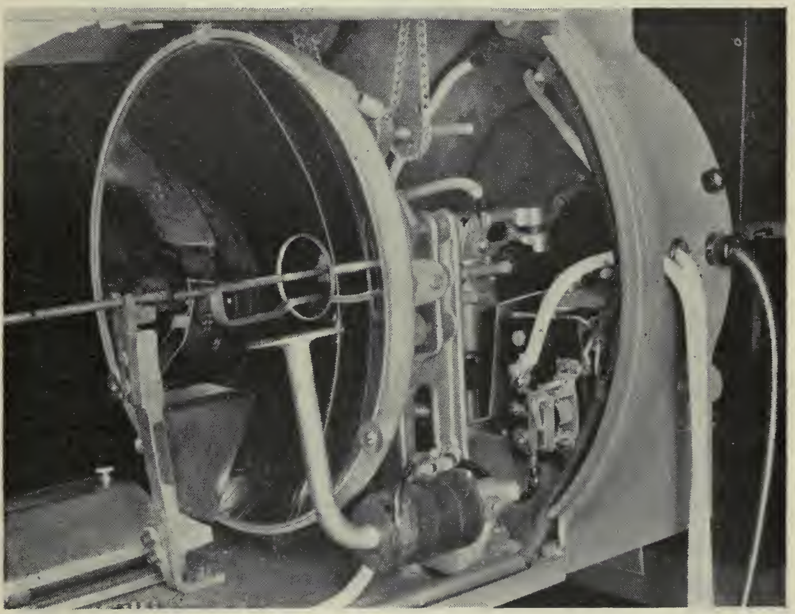

Fig. 6

practice to place either a permanent or electromagnet in the lamphouse, positioned in a manner so that this inherent magnetic field is partially neutralized to give a better burning characteristic to the arc. This type of arc is called a "Suprex" arc and also a "Simplified High-Intensity" arc. While it is a great improvement over the previous

Fig. 7

Fig. 8

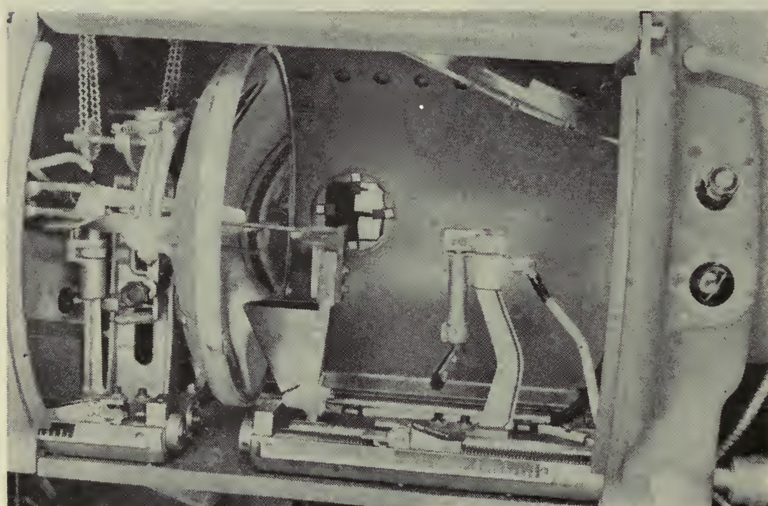

Fig. 9

type of arc known as low intensity, it is still not the ultimate to be desired for very large theaters.

In the lamphouse used with the new feeding mechanism described here, a polarized directional electromagnet is provided. This supplies a strong polarized magnetic effect which causes the arc to burn with a very long and narrow tail flame rising straight up at right angles to the arc and with little enveloping flame. Fig. 7 shows the shape of the tail flame as compared with that of the "Suprex" arc shown in Fig. 8. The magnet is shown in Fig. 6 (bottom center). The horn of the magnet has a target at its upper end and it may be

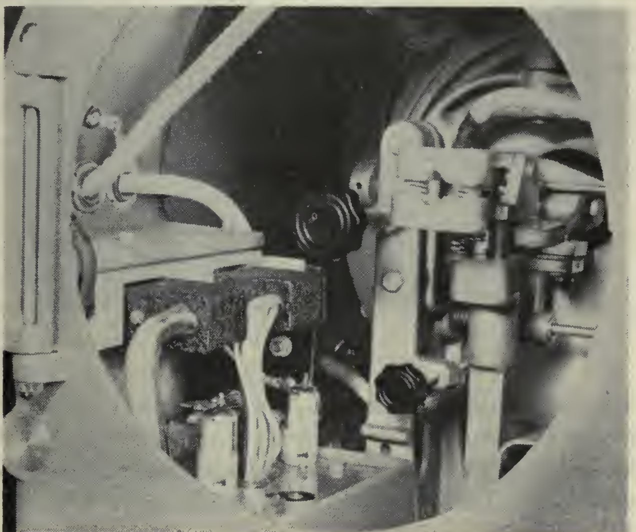

Fig. 10

adjusted vertically or horizontally on its axis. Once the magnet has been initially set up, no further adjustment is necessary, through the complete amperage range of the arc (40 to 90 amperes).

Other features of the lamp design include a warning light which indicates when the carbon has burned beyond the point at which it will last through another reel of film. Both carbon carriers also have scales and pointers indicating remaining burning life.

Fig. 9 shows the working side of the lamp with the door open and the flame shield raised. Fig. 10 is a view through the back door of the

lamp showing both electronic timers with covers removed. Fig. 11 is a side view showing control knobs for adjusting the carbon feeds. All the electric wiring in the lamp is shielded and the wire covered with asbestos braid. The reflector is elliptical, 14 inches in diameter for currents to 75 amperes and 16 inches for currents from 75 to 90 amperes, with a center hole $2^1/_2$ inches in diameter through which the

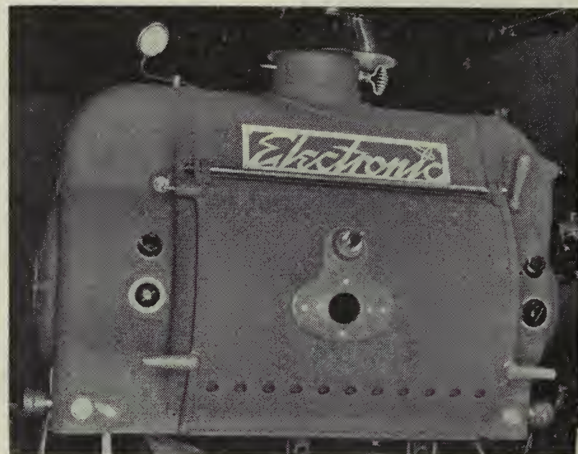

Fig. 11

negative carbon, carbon holder, and carbon guide pass horizontally. A flame shield is provided which protects the reflector when the arc is struck, and moves out of the way when the light gate is opened to pass the light to the projector. The positive carbon guide is provided with a removable chute or shield which carries the copper drippings from the carbon into an easily removable receptacle.

Industrial Sapphire in Motion Picture Equipment

By WALTER BACH

Berndt-Bach, Inc., Los Angeles, California

and

CHRIS WAGNER

Elgin National Watch Company, New York, N.Y.

Summary—This paper is an endeavor to call attention to an engineering material which has the most favorable coefficient of friction in relation to film emulsions and bases among known commercial products.

Characteristics of sapphire in fine watches, the development of industrial sapphire, and potential motion picture equipment applications are discussed briefly. The Auricon camera film gate with regard to the use of hard contact points and the mounting of sapphire contact surfaces is described and illustrated. Physical characteristics of sapphire are shown with charts and performance data. Diamond lapping compounds and the metal bonding and flame forming of sapphire are briefly mentioned.

Synthetic sapphire jewels have the most favorable coefficient of friction in relation to film emulsions and bases among known commercial products. This friction characteristic is due to sapphire's monocrystalline structure and complete lack of porosity, coupled with extreme hardness and resistance to abrasion.

The value of these physical characteristics has been demonstrated for over a century in the jeweling of fine watches, first with natural stones, and of late years with synthetic sapphire which is comparable in hardness and not subject to the flaws found in the natural product.

Every individual who possesses a fine watch carries from seven to twenty-one pieces of sapphire on his person daily, with scarcely a thought that these sapphire jewels represent the most accurate and certainly the most dependable and enduring components of the time-measuring mechanism.

Many engineers are familiar with the amazing magnitude of balance oscillations and escapement action of a watch, but few realize that, in spite of 432,000 impulse and locking cycles each day, the sapphire pallet stones show no wear in a lifetime of service.

Industrial sapphire, or corundum, has been man-made for some fifty years and until the last few years was largely a European product

Presented: May 20, 1948, at the SMPE Convention in Santa Monica.

limited in scope of application by the small size of available raw material. Under the impetus of war demands for jewel bearings, industrial or synthetic sapphire is now produced commercially in the United States.

Industrial sapphire is an artificially grown crystal, formed through an oxygen-hydrogen flame. The alumina, melting and impinging on a refractory pedestal in a high-temperature furnace, grows as a boule or a rod according to the rate at which the pedestal is withdrawn. Rods are commercially grown over a range of diameters to slightly over 0.250 inch and between 2 and 6 inches in length. Boules are roughly 0.750 inch in diameter, limited in length, and average about 200 carats. Tubing, disks and other shapes have been produced experimentally and boules as large as 800 carats have been grown.

Fabrication is primarily by diamond-charged saws and laps, with a relatively new technique of flame forming and flame polishing finding increasing application.

The question now is whether industrial sapphire can find a place for itself in motion picture equipment. The potential motion picture applications fall roughly into four classifications: (1) Where the material is urgently needed because of partial failure of existing components, resulting in danger of film damage. (2) Where film footage is sufficient to indicate marked economy in terms of greatly increased life of film or machine components. (3) Where an additional safeguard could be afforded against film-base scratches and emulsion pickup. (4) Where a design advantage is afforded in the mechanism entirely apart from contact of sapphire itself.

Let us consider current research applications of sapphire in the film gate of the 16-mm "Auricon-Pro" single-system sound-on-film camera.

The Auricon camera has a claw intermittent and it is necessary that the pressure plate maintain the negative in a steady position as the claw leaves the perforation and throughout the time of shutter opening in order to secure a steady in-register picture. It is also necessary that the pressure plate take out the natural film curl and hold the film flat and perfectly in focus at the aperture. This means that one must exert confining forces on the film during shutter opening, and since the pressure plate is of the spring-loaded, constant-pressure type, those same forces are present during the pulldown cycle. To prevent scratching of acetate film base and picking up of emulsion the friction coefficient of the gate must be favorable to the film.

Fig. 1—16-mm "Auricon-Pro" single-system sound-on-film camera.

Like many other devices in the industry, the "Auricon-Pro" camera film gate has gone through years of evolution and redesign. These changes have been influenced by the fact that simplicity of design required the film to be confined with appreciable pressures throughout the entire intermittent cycle, and placed severe requirements upon materials used in the film-gate construction.

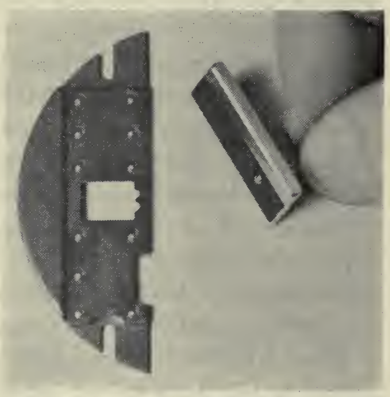

Fig. 2—Auricon aperture and pressure plates.

Within the past year Berndt-Bach redesigned the "Auricon-Pro" camera gate to permit the use of hard contact points in the aperture plate so located that these contacts do not touch either the picture or sound track area of the film emulsion. In the back pressure plate a single contact

is located directly behind the center of the aperture. The film is fully confined and in focus at the actual aperture area. The eleven aperture plate contacts are located to secure distribution of the pressure forces over the entire aperture plate, in addition to providing film support at the aperture opening and at the entering and leaving positions of the pulldown claw.

At the time of this redesign we believed the use of highly polished hard-chrome-steel balls offered a favorable material. Initial tests proved satisfactory, but it became evident that these balls in contact with film emulsions developed pits and corroded to an extent that nullified the advantages of their original mirror polish and hardness.

The hard-chrome-steel balls were then replaced with balls of a special stainless steel of the same diameter, to secure improved corrosion-resistant qualities. Realizing that these stainless-steel balls would be subject to surface abrasion from acetate film base and emulsion regardless of original fine surface finish, the balls were lapped and polished after assembly to provide a tiny flat on each and slightly increase the contact area. This application has produced the most satisfactory Auricon camera film gate thus far obtained with metals, and patent applications have been allowed on this construction.

Concurrently, investigation of the possible uses of industrial sapphire in this application was undertaken, since the redesign was based on an endeavor to secure point or very small area contacts of extremely hard, nonporous material located in emulsion areas which would not encroach on picture or sound track.

Sintered carbide materials, which offered excellent hardness and resistance to film abrasion, were ruled out on the two counts of porosity and unfavorable friction coefficient.

Application of industrial sapphire was contemplated from the inception of the program. Short of diamond, sapphire offers the best combination of hardness, nonporosity and friction coefficient qualities, and the additional advantage of a monocrystalline structure.

Clear sapphire balls of approximately $^3/_{32}$ inch in diameter were inserted in the Auricon-Pro camera gate. (There is no practical difference between the clear and the ruby-red sapphire, aside from color.) With the single-point ball contact of the back pressure plate directly behind the center of the aperture, no difficult sapphire-ball-mounting problem exists. However, with the eleven ball contacts of the aperture plate it is not only desirable that the multiple inserts cumulatively form a perfectly flat plane but, in the case of those im-

mediately surrounding the aperture, a must. This can be maintained by carefully pressing in the contacts to uniform height or, preferably from a production standpoint, by flat-finish lapping with fine diamond compound. In this case even a very slight lapping to produce a small polished flat on the spherical surface considerably increases the contact area and provides a safer margin for film gate pressure-plate loading.

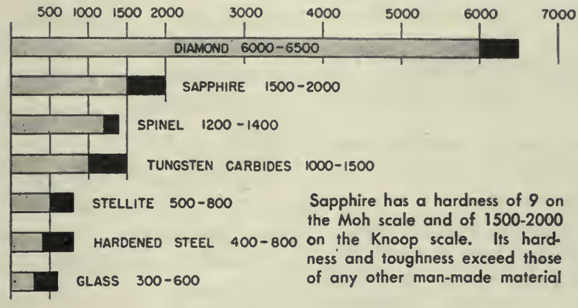

Fig. 3. Hardness chart.

Physical Characteristics of Sapphire

Sapphire offers the motion picture industry some remarkable physical characteristics, the most favorable of which is its friction coefficient in relation to film. Use of the material has been limited to a very few applications in the industry, of which we might mention the use of sapphire jewel bearings and film-edge guides.

Table I will serve to suggest, merely on the basis of physical characteristics, where sapphire will find worth-while application. We see no need to suggest that sapphire indiscriminately replace existing components. Where no present vital problem exists there is little need to seek an immediate solution. However, in contemplating redesign of existing equipment, or development of new devices, the designer can hardly ignore consideration of so favorable an engineering material.

A note to the designing engineer would not be amiss, in calling to his attention that sapphire becomes a fragile material when subjected to shock of various natures. Sapphire subjected to severe mechanical shock might lead one to believe that data on compressive strength and elastic characteristics is in the nature of a snare and a delusion. We emphasize this despite personal tests wherein ruby jewels of 0.015 inch in thickness were placed on a steel plate and vigorously pounded with a pyralin hammer, without breakage.

TABLE I. SAPPHIRE PRODUCTS

(Technical Data)

Properties of Synthetic Sapphire

Chemical Formula—Al_2O_3
Melting Point—2050 °C–3722 °F
Crystal System—Hexagonal
Chemical Resistance—Not affected by any known chemical at room temperatures
Modulus of Rupture—59,000 to 125,000 pounds per square inch approximately
Compressive Strength—300,000 pounds per square inch
Water Absorption—0
Density, lb. per cubic inch—0.144
Specific Gravity (Water = 1)—3.99
Elastic Modulus—Steel—30,000,000
Sapphire—55,000,000
Refractive Index—1.757, 1.765
Thermal Conductivity—0.007 $cal.sec.^{-1} cm.^{-1} °C^{-1}$
Thermal Coefficient of Expansion—3.3 × 10–6 per degree Fahrenheit average
Dielectric Constant—7.5–10.0
Stability on Aging—No change

Specific Heat

Silver	0.05
Copper	0.09
Steel	0.10
Glass	0.16
SAPPHIRE	0.18
Porcelain	0.26

Hardness and Toughness

	Hardness (Knoop Scale)	Toughness (Relative)*
Diamond	6,000–6,500	2
Boron Carbide	2,200	4
SAPPHIRE	2,000	3
Tungsten Carbide	1,000–1,500	2
Hard Chromium Plate	850–900	1
Stellite	500–800	1
Steel, Rockwell C65–67	791	1
Crystalline Quartz— Parallel to axis	710	
Perpendicular to axis	790	4
Steel, Rockwell C47	496	1
Fused Quartz	475	4
Crown Glass	420–470	5

*Comparative order of toughness, highest being number one.

Coefficient of Friction Against Steel

Sapphire	0.14
Graphite	0.16
Leaded Brass	0.19

Shock of another nature to which sapphire should not be subjected is thermal shock, or sudden changes in temperature. This should be taken into consideration when designing with a view to using the new metal-bonding techniques. Until recently, solder recommendations in connection with soldering metal-bonded sapphire shapes have been limited to low-temperature solders. However, silver soldering of metal-bonded sapphire shapes is becoming practical.

Extended research has been undertaken in the technique of flame forming and finishing of sapphire. In the process, sapphire is heated to a very high temperature in an oxidizing atmosphere and can be formed by "slipping" the planes of the crystal. In spite of very drastic deformation in shape the sapphire still maintains a monocrystalline character. During this operation the surface of the material flows to form a very high surface finish. Thus far, flame forming is limited to rod stock under 0.125 inch in diameter. Pigtail thread guides formed by 360-degree bends in sapphire rods offer an excellent illustration of the possibilities of flame forming.

Applications of sapphire to motion picture equipment are few in number and too limited to enable one to make an accurate estimate of the full worth of this newly advailable material at the present time. Friction coefficients, resistance to abrasion, hardness, physical stability, and other vital qualities have been demonstrated through applications in other industries. In sapphire we are dealing with an engineering material of known characteristics and increasing availability, in which the field of potential application is still largely unknown.

One of the most interesting potentials appears when we think of film as an abrasive textile, abrading to a greater or less degree each surface with which it comes in contact during its life span, and in turn being itself abraded through the deterioration of those same surfaces. The thought of introducing sapphire surfaces at critical or strategic locations along that film path then becomes interesting indeed.

DISCUSSION

CHAIRMAN WATSON JONES: Are there any questions?

MR. SAUTER: With reference to precision bearings for mechanical engineering use, what class of accuracy compared to standard precision bearings could we obtain in ball bearings?

MR. CHRIS WAGNER: Balls are being made to an accuracy of twenty-five millionths sphericity and 0.0002 inch for diameter. The diameter tolerance could be reduced further if necessary for application in ball bearings.

MR. SAUTER: In high-speed work what type lubricant would you need?

MR. WAGNER: The practical value of sapphire in high-speed work is the elimination of lubricant. It will run dry in contact with steel races or with sapphire races.

MR. SAUTER: How does the cost compare with high-precision regular ball bearings?

MR. WAGNER: The cost is higher. In $^1/_{16}$ balls the cost is about sixteen cents per ball, and as the balls get larger the cost goes up. However, it does offer possibilities in engineering work where the ball bearings are subject to extreme speed or to corrosion.

Report of SMPE Standards Committee

By FRANK E. CARLSON, Chairman

General Electric Co., Nela Park, Cleveland

In his report[1] as retiring chairman of the Standards Committee, F. T. Bowditch offered several suggestions for improving the effectiveness of the Committee. Briefly, he proposed that the development of standards could most properly be done by the several engineering committees of the Society and that the past practice of organizing subcommittees of the Standards Committee to prepare such standards should be discontinued wherever possible. Further, he proposed that the Committee on Standards should be so organized that it functions primarily as a policy-making group, but it should also be competent to consider the over-all effect of standards proposals in relation to the industry and to related standards.

These recommendations were promptly adopted by the present chairman and, as a result, the Standards Committee has been functioning in substantially the manner envisioned by Bowditch. Since the new plan obviously called for close co-operation with each of the engineering committees and since the chairmen of such committees are obviously qualified in their respective fields, it was felt that a first step toward a representative policy-making group would be to invite these chairmen to serve as members of the Standards Committee. The second step was to include as members the chairmen of the several ASA sectional committees having interests closely related to the motion picture industry. A third and final step was to solicit the participation of the Motion Picture Research Council and of only a few of the many members of the Society who, either because of special knowledge or long experience with standardization problems, could be of outstanding assistance to the committee. The Engineering Vice-President approved this plan, and the present committee has been in operation since its appointment early in 1948.

The accomplishments of the present Committee are properly credited to the several engineering committees identified with the projects briefly described in the balance of this report.

Presented: As of December 31, 1949.

FILM DIMENSIONS

A Subcommittee on Cutting and Perforating Raw Stock had been in existence since November, 1945, under the chairmanship of Dr. E. K. Carver. Since that date the subcommittee has completed several assignments, but it was apparent that much standardization of film dimensions remained to be done. Accordingly, the Standards Committee recommended to the Engineering Vice-President the formation of an engineering committee to deal with such problems. In this particular field the Standards Committee has acted on the following:

1. Reaffirmed[2] the American Standard for cutting and perforating 35-mm negative raw stock (Z22.34–1944).
2. Recommended for adoption as standards by ASA two of three proposed 32-mm cutting and perforating standards which had been published[3] for a period of trial and criticism in the JOURNAL. Not approved was the third proposed standard, related to cutting and perforating 32-mm on 35-mm motion picture negative raw stock. It was tabled because several members were opposed to having nitrate stock perforated in this fashion because of the possibility of its being slit to 16-mm and used on conventional 16-mm projection equipment.
3. Referred back to the Film Dimensions Committee the proposed American Standard, "35-mm Motion Picture Combination Positive-Negative Raw Stock, Z22.1" which had been published[4] for a period of trial and criticism in the JOURNAL. Final action on this proposal has been deferred pending the outcome of additional tests of the suitability of the proposed perforations.

16-MM AND 8-MM MOTION PICTURES

The subject of standards relating to sprockets continues to be the most difficult problem in this category confronting the Committee. The entire Committee is in agreement as to the merits of the design practice described by Chandler, Lyman, and Martin[5] to insure good performance with film. The Committee, however, cannot agree that such a practice can properly become an American Standard. Accordingly, the Committee has asked for and obtained approval from the Board to publish an abridgement of the Chandler, Lyman and Martin paper in a format suitable for inclusion in the Standards binder of the Society as an SMPE recommendation on sprocket design. This abridgement is scheduled for publication in an early issue of the JOURNAL.

Concurrently, the Standards Committee has recommended the withdrawal of the following two standards relating to this subject which are now obsolete: (1) American Standard for 8-mm Motion Picture Film Eight Tooth Projector Sprockets (Z22.18–1941); and (2) American Standard for 16-mm Motion Picture Film Projector Sprockets (Z22.6—1941).

A subcommittee of the Standards Committee and, later, the 16-mm and 8-mm Motion Pictures Committee has been in the process of reviewing and revising the six present standards relating to 16-mm and 8-mm picture apertures. The Standards Committee has approved four proposed standards[6] to take the place of the present six standards and has recommended their adoption as standards by ASA and the rescinding of the two superfluous standards Z22.13–1941 and Z22.14–1941.

The 16-mm and 8-mm Motion Pictures Committee has also completed work on three new standards which the Standards Committee has approved for a period of trial and criticism. These three proposed standards have been published[7] in the JOURNAL and relate to:

1. Mounting threads and flange focal distances for lenses on 16-mm and 8-mm motion picture cameras.
2. A base point for focusing scales on 16-mm and 8-mm motion picture cameras.
3. Winding of 16-mm sound motion picture film.

The first two proposed standards are intended to replace war standards developed under the war procedures of the ASA for use of the Armed Services. The third proposal is intended to formalize a practice in use by film manufacturers for a number of years and which the SMPE, in 1941, adopted as a recommended practice.

A new standard relating to splices for 16-mm motion picture films will soon be published in the JOURNAL for a period of trial and criticism. This proposed standard, if adopted, will replace the two existing standards, Z22.24–1941 and Z22.25–1941, relating to silent and sound films respectively and is intended to apply only to projection films. The Standards Committee feels that a separate standard for negative films is also needed and the 16-mm and 8-mm Motion Pictures Committee has been asked to consider this matter.

The 16-mm and 8-mm Motion Pictures Committee has also proposed a revision of Z22.11–1941 relating to 16-mm motion picture projection reels. The Standards Committee is, at the present time,

reviewing this proposal and may approve it for publication in the JOURNAL for a period of trial and criticism.

PHOTOMETRIC CALIBRATION OF CAMERA LENSES

Since there is no engineering committee of the Society that is prepared to take over this project, it has continued to be handled by a subcommittee of the Standards Committee under the able chairmanship of Mr. Kingslake. A report of Mr. Kingslake's subcommittee has been recently published[8] in the JOURNAL and the subcommittee has been requested to prepare this material in a form suitable for consideration as a proposed standard.

OBSOLETE STANDARDS

It is obviously important that the Standards Committee not only encourage the processing of new standards beneficial to the industry but also recommend the withdrawal of old standards which have become obsolete or which, by their continued existence, impede progress. Accordingly, the following standards have been reviewed by engineering committees, and, as a result of their findings, the Standards Committee has recommended withdrawal: (1) American Recommended Practice for Motion Picture Film Sensitometry (Z22.26–1941); and (2) American Recommended Practice for Motion Picture Engineering Nomenclature (Z22.30–1941).

REFERENCES

(1) "Report of the Standards Committee," *Jour. SMPE*, vol. 51, pp. 230–241; September, 1948.

(2) "Standards recommendations," *Jour. SMPE*, vol. 52, p. 358; March, 1949.

(3) "Three proposed American Standards," *Jour. SMPE*, vol. 52, pp. 223–230; February, 1949.

(4) "Proposed American Standard," *Jour. SMPE*, vol. 52, pp. 447–452; April, 1949.

(5) "Proposals for 16-mm and 8-mm sprocket standards," *Jour. SMPE*, vol. 48, p. 483; June, 1947.

(6) "Proposed standards for 16-mm and 8-mm picture apertures," *Jour. SMPE*, vol. 52, pp. 337–348; March, 1949.

(7) "Proposed American Standards—16-mm and 8-mm," *Jour. SMPE*, vol. 53, pp. 293–300; September, 1949.

(8) "Report of lens calibration subcommittee," *Jour. SMPE*, vol. 53, pp. 368–378; October, 1949.

New American Standards

THE TWO TEST FILM STANDARDS that appear on the following pages were proposed initially and developed by the Motion Picture Research Council. After being subjected to careful study under the normal procedure of American Standards Association Sectional Committee on Motion Pictures Z22, they were approved for publication and have now been added to the list of available standards.

An up-to-date index listing these and several other changes made during the past year has just been prepared and copies are available to all who use motion picture standards for reference.

Within the last two or three weeks copies were sent free of charge to all whose names are on the Standards Mailing List. If you have one of the Society's "American Standards Binders" and have not yet received the green index dated January 1, 1950, send your name and address to Boyce Nemec, Executive Secretary, and your index will be sent by return mail.

The addresses of all who inquire will be placed on the Binder List to be notified each time new or revised standards are approved for publication.

A number of recent Proposals for Standardization and all of the American Standards shown in the index have been printed or reported upon in one or more of the following issues of the JOURNAL:

1946	April	page 284	1949	February	page 223
	September	258		March	337
1947	August	171		April	434
	December	547			& 447
1948	March	280		August	211
	November	534		September	293

American Standard

Sound Focusing Test Film for 35-Millimeter Motion Picture Sound Reproducers (Service Type)

ASA
Reg. U. S. Pat. Off.
Z22.61-1949

*UDC 778.5

1. Scope and Purpose

1.1 This standard describes a film which may be used for focusing the optical systems in 35-millimeter motion picture sound reproducers. The recorded frequency shall be suitable for use in the routine maintenance and servicing of the equipment.

2. Test Film

2.1 The film shall be a print from an original negative and shall contain a 7000-cycle, sinusoidal, variable-area or variable-density track recorded at 1 decibel below 100-percent modulation. The variation in power output level from the film shall be not more than ±0.25 decibel.

2.2 The sound track shall comply with American Standard Sound Record and Scanned Area, Z22.40-1946, and the film stock used shall be cut and perforated in accordance with American Standard Cutting and Perforating Dimensions for 35-Millimeter Motion Picture Raw Stock, Z22.36-1947, or any subsequent revision thereof.

NOTE: A test film in accordance with this standard is available from the Motion Picture Research Council or the Society of Motion Picture Engineers.

Approved February 4, 1949, by the American Standards Association, Incorporated.
Sponsor: Society of Motion Picture Engineers.

*Universal Decimal Classification

American Standard

Buzz-Track Test Film for 35-Millimeter Motion Picture Sound Reproducers

ASA
Reg. U. S. Pat. Off.
Z22.68-1949

*UDC 778.534.4

1. Scope and Purpose

1.1 This specification describes a film which may be used for checking the lateral scanning slit placement of 35-millimeter motion picture sound reproducers.

2. Test Film

2.1 The test film shall be a direct positive recording or a print from an originally-recorded negative and shall contain 300-cycle and 1000-cycle square-wave tracks on either side of the central exposed strip as shown in Fig. 1.

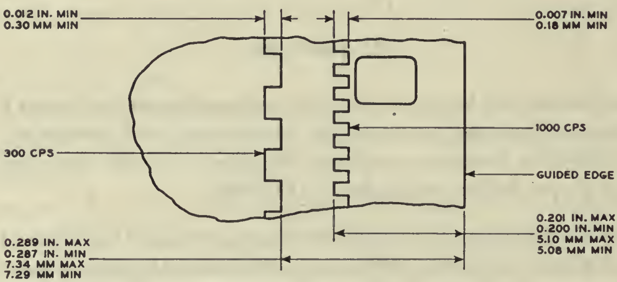

Fig. 1

2.2 The central exposed strip and the exposed portion of the two signal tracks shall have a minimum density of 1.4 and a maximum density of 2.0.

2.3 The film stock used shall be cut and perforated in accordance with the American Standard Cutting and Perforating Dimensions for 35-Millimeter Motion Picture Positive Raw Stock, Z22.36-1947, or the latest revision thereof approved by the American Standards Association, Incorporated.

2.4 The film stock used shall have a shrinkage of not more than 0.50 percent.

NOTE: A test film in accordance with this standard is available from the Motion Picture Research Council, or the Society of Motion Picture Engineers.

Approved May 23, 1949, by the American Standards Association, Incorporated.

Sponsor: Society of Motion Picture Engineers.

*Universal Decimal Classification

New Officers of the Society

Members who were elected during the annual Society elections in 1949 took office on the first of January. So that Society members who have recently joined may become better acquainted with these men who are responsible for managing the affairs of the Society, here they are:

Engineering Vice-President

Fred T. Bowditch has been closely associated with Society administration for many years, having served several terms as a member of the Board of Governors. This year he vacates the second half of a two-year Governorship, in order to become Engineering Vice-President for 1950 and 1951; and, so that he may devote a major part of his time to the important engineering committee work of the Society, he has also resigned from the Chairmanship of Committee Z22, the Sectional Committee on Motion Pictures of the American Standards Association. Since last October Mr. Bowditch, John A. Maurer, outgoing Engineering Vice-President and Bill Deacy, Society Staff Engineer, have been reviewing committee appointments and projects, with an eye toward the easy transfer of responsibilities, as well as the gradual expansion of the work of our many technical committees.

Mr. Bowditch is Director of Illuminating Carbon Research for the National Carbon Company, Box 6087, Cleveland 1.

Financial Vice-President

Ralph B. Austrian moves from the office of Treasurer which he held in 1948 and 1949 to become Financial Vice-President for 1950–1951. He replaces David B. Joy, who retires from the Board of Governors this year after a number of years of very active service to the Society.

Long associated with the sound recording and theater equipment part of the motion picture industry, Mr. Austrian has more recently been active in the field of television. He is currently doing consulting work in television broadcasting and also in theater television. He may be reached at 25 West 54th St., New York 19.

Treasurer

Frank E. Cahill becomes Treasurer of the Society for 1950 and 1951, replacing Mr. Austrian. Having been a member of the Society for nearly twenty years, with many years of service on the Board of Gov-

ernors and on several engineering committees, Mr. Cahill is well known to the Society and to the motion picture industry. During the recent war, he was Executive Officer of Army Pictorial Service and at the end of the war, he reassumed his duties as Technical Director of Warner Bros. Circuit Management Corp., 321 West 44th St., New York 18.

Governors

Lorin D. Grignon begins his first term on the Board of Governors after a number of active years with the Pacific Coast Section of the Society. "Flicker in Motion Pictures" has long been a topic of major interest for Mr. Grignon and more recently he has been active in television film and theater television matters on the West Coast. He is an engineer in the Studio Sound Department at Twentieth Century-Fox Films, Inc., Box 900, Beverly Hills, Calif.

Paul J. Larsen was elected last year to his third successive term as a Governor of the Society. His interest in theater television continues although he is currently occupied with other matters. He may be reached at 508 S. Tulane St., Albuquerque, N.M.

William H. Rivers has served two one-year terms as Chairman of the Atlantic Coast Section of the Society, which made him an ex-officio member of the Board for 1948 and 1949. As a result, members in and near New York City are well acquainted with him. He now begins his first two-year term as an elected Governor and may be reached at Eastman Kodak Company, 342 Madison Ave., New York 17.

Edward S. Seeley was a Manager of the Atlantic Coast Section for a two-year term which ended in December, 1949, and he now becomes a Governor for 1950 and 1951. Having been Chief Engineer of Altec Service Corp. for a number of years, Mr. Seeley is well known in the audio-engineering and theater equipment fields. His office is at Altec Service Corp., 161 Sixth Ave., New York 13.

R. T. Van Niman has served two successive terms as Chairman of the Central Section, for 1948 and 1949. In 1948 he was elected to two Society offices: Central Section Chairman for 1949 and Society Governor for 1949 and 1950. He chose to resign the Governorship in order to devote more time to the work of the Section. He now retires from the Section Chairmanship and has once again been elected as a Governor, this time for 1950 and 1951. As a member of the sound committee for several years he was Chairman of the Subcommittee on Phototubes. He is a sound engineer for Motiograph, Inc., and may be reached at 4501 Washington St., Chicago 24.

John P. Livadary was elected in 1949 to fill a one-year West Coast Governorship vacancy. The unfilled position was left vacant by the resignation of S. P. Solow who in 1948 was elected to two Society offices and chose to retain the Chairmanship of the Pacific Coast Section. Mr. Livadary is a member and friend of the Society of long standing who now begins his first term on the Board. Having been Sound Director of Columbia Pictures for many years, he is active in the work of the Motion Picture Research Council and of our own sound committee, and may be reached at 4034 Cromwell Ave., Los Angeles 27.

Section Officers

The Atlantic Coast Section Chairman for 1950 is Edward Schmidt, Technical Representative for Reeves Sound Studio, 304 East 44th St., New York 17. The Secretary-Treasurer is Harry Milholland, head of the Tele-Transcription Department at Allen B. Du Mont Laboratories, Inc., 515 Madison Ave., New York 22.

Central Section Chairman is George W. Colburn, President of George W. Colburn Laboratories, 164 No. Wacker Drive, Chicago 6. The Secretary-Treasurer is C. E. Heppberger, Lighting Carbon Technical Specialist, National Carbon Company, Inc., 230 No. Michigan Ave., Chicago 1.

Pacific Coast Chairman is Charles R. Daily, Optical Engineer, Paramount Pictures, Inc., 5451 Marathon St., Hollywood 38,. Calif. The Secretary-Treasurer is Vaughn C. Shaner, Technical Service, Eastman Kodak Company, 6706 Santa Monica Blvd., Hollywood 38, Calif.

Engineering Committees

In addition to appointing new chairmen for several of the Society's eighteen engineering committees, F. T. Bowditch, newly elected Engineering Vice-President, and Bill Deacy, Society Staff Engineer, have just completed an impressive schedule of engineering committee projects for 1950. Most of them are a continuation of work that was begun during 1949 or earlier, but several of the projects are entirely new. One example concerns a special leader for 16-mm television films that would replace the conventional "academy" leader that is generally not favored by television film users. One of the requirements of the

new leader is that it give an accurate "on the air" cue for both the television projector operator and the program director. This is a serious matter to television broadcasters since film must be cued to start on the second with no such liberal tolerances as are standard practice in theaters.

Another of the new projects, and one that was suggested by the Technical Editor of a motion picture trade magazine, has to do with possible standards or recommendations for air conditioning of theater auditoriums.

So that members may keep posted throughout the year on the current status of these and other projects, each issue of the JOURNAL for 1950 will review some of the work of several engineering committees. This is something new and Bill Deacy would appreciate comments on this method of reporting.

Frank E. Carlson of General Electric, Nela Park, Cleveland, has just been appointed Chairman of the Standards Committee for his second consecutive two-year term. In this issue of the JOURNAL he reports on changes made in the organization of the Standards Committee when he became chairman early in 1948, and on the accomplishments of the committee over the past two years. During that time the Standards Committee has served primarily as a policy-making body, supervising the Society's standardization activities and advising the Engineering Vice-President. A careful study of Mr. Carlson's report will give a good working knowledge of the way in which standards are developed; and his report should be of interest to members who either use these American Standards or participate in some phase of the Society's committee work.

The final result of almost any engineering project has in the past been either a specific formal standards proposal or a detailed committee report which, though generally not as concise as a standard, has served to document a particular chapter or phase of our engineering history. For some time we have needed an "in-between" type of document, less formal than a standard but more specific than the customary committee report. It should be a way of presenting committee recommendations as a series of reference publications on subjects that do not lend themselves readily to standardization under rigid ASA procedures. To fill this gap, the Society's Board of Governors recently approved publication of "Society Recommendations." A description of this new type of publication is part of the report of the President for 1949 that appears in this issue.

1950 Nominations

All Active, Fellow and Honorary members may recommend candidates for the ten vacancies on the Board of Governors which will occur on December 31, 1950. Suggestions should be mailed early so that they will certainly be in the hands of the Nominating Committee prior to May 1, 1950. They may be addressed to the Chairman or to any of the members of the Committee:

D. E. Hyndman, *Chairman*
Room 626, 342 Madison Ave., New York 17.

Herbert Barnett
General Precision Equipment Corp.
63 Bedford Road, Pleasantville, N.Y.

F. T. Bowditch
Research Laboratories
National Carbon Company
Box 6087, Cleveland 1.

F. E. Cahill, Jr.
Warner Bros. Pictures, Inc.
321 West 44th St., New York 20.

R. E. Farnham
General Electric Company
Nela Park, Cleveland 12.

G. R. Giroux
Technicolor Motion Picture Corp.
6311 Romaine St., Los Angeles 28, Calif.

A. N. Goldsmith
597 Fifth Ave., New York 17.

T. T. Goldsmith
Allen B. Du Mont Laboratories
2 Main Ave., Passaic, N.J.

K. F. Morgan
Western Electric Company
6601 Romaine St.,
Hollywood 38, Calif.

The Board members whose terms expire at the end of this year are:

President, E. I. Sponable
Executive Vice-President, Peter Mole
Editorial Vice-President, C. R. Keith
Secretary, R. M. Corbin
Convention Vice-Pres., W.C. Kunzmann
Governor (East), Herbert Barnett
Governor (East), (vacant)
Governor (West), K. F. Morgan
Governor (West), J. P. Livadary
Governor (West), N. L. Simmons

Society Awards for 1950

Each year the Society considers candidates for five awards on the basis of the qualifications outlined briefly here. Further details concerning these awards are published in the April issue of the Journal each year for the information of members who may not be familiar with them. Suggestions or questions concerning these matters may be addressed to the chairman of any of the award committees or to the Executive Secretary at Society Headquarters in New York.

Fellow Award

Members in the Active grade who by their " . . . proficiency and contributions have attained outstanding rank among engineers or executives of the motion picture industry" may be proposed and con-

sidered as possible award nominees by the Fellow Award Committee. Such proposals will be received only from present Fellows of the Society and should be addressed to Loren L. Ryder, Committee Chairman and Past-President of the Society. His address is: Paramount Pictures, Inc., 5451 Marathon St., Hollywood 38, Calif.

Honorary

The Honorary Membership Award is a distinction given to pioneers who have contributed inventions of basic importance to the industry or whose contributions have made possible better production, administration or utilization of motion pictures. Recommendations for the Honorary Membership Award may be submitted by any member of the Society and must be endorsed by at least five Fellows, who are required to set forth in writing their knowledge of the accomplishments which appear to justify presentation of the Award. Such recommendations must be addressed to the Honorary Membership Committee Chairman, Gordon A. Chambers, Motion Picture Film Dept., Eastman Kodak Company, 343 State St., Rochester 4, N.Y.

Journal Award

The Journal Award is presented annually at the Fall Convention of the Society to the author of the most outstanding paper originally published in the Journal of the Society during the preceding calendar year. Technical merit, originality and excellence of presentation are three major considerations. The authors of papers of nearly equivalent merit often receive Honorable Mention. The Journal Award Committee, appointed by the President, is now under the Chairmanship of Dr. C. R. Daily, who will shortly be receiving from members of his Committee, their recommendations for the most outstanding paper for 1949. His address is: 5451 Marathon St., Hollywood 38, Calif.

Samuel L. Warner Memorial Award

Each year the President appoints a Samuel L. Warner Memorial Award Committee to consider candidates for the Award. Preference is given to inventions or developments occurring in the last five years, and also to inventions or developments likely to have the widest and most beneficial effect on the quality of reproduced sound and picture. The Award is made to an individual and may be based upon his contributions of the basic idea involved in the particular development being considered and also on his contributions toward the practical working out of the idea. The purpose of the Award is to encourage the development of new and improved methods or apparatus designed for sound on film motion pictures, including any step in the process.

The present Chairman of the Committee is W. V. Wolfe, Motion Picture Research Council, 1421 North Western Ave., Hollywood 27, Calif.

Progress Medal Award

Written recommendations for candidates for the Progress Medal Award may be submitted by any member of the Society, giving in detail the accomplishments which appear to justify consideration. Qualifications should include invention, research, or development which has resulted in a significant advance in the development of motion picture technology and should be seconded in writing by any two Fellows or Active members of the Society, after which the recommendations must be filed with the Chairman of the Committee. For 1950, the Chairman is Dr. J. G. Frayne, Westrex Corp., 6601 Romaine St., Los Angeles 38, Calif.

Society Announcements

Membership Directory 1950

The Society's *Membership Directory* for 1950 is scheduled for early publication, so members are urged to reply promptly to the questionnaire-envelope enclosed with the 1950 membership dues statement. Since the *Directory* is published every two years, addresses and company affiliations must be corrected now, or stand uncorrected till 1952. Please send yours in now if it has not already been mailed.

Section Meetings

The first regular meeting of the *Atlantic Coast Section* in 1950 is scheduled for 7:30 P.M., January 18, at the RKO Pathé Studios, 105 East 106th St., New York City. Ed Schmidt, Section Chairman, reports that Drs. E. B. Jennings and A. B. Weiss will describe and demonstrate the new du Pont release positive color film. This is to be a somewhat condensed version of several du Pont papers on the new Type 275 film that were presented during the 66th Convention in Hollywood last October.

Attendance should be excellent since this will be the first opportunity that many East Coast members of the Society have had to look over this much discussed new film.

The *Central Section* meets at 8:00 P.M., January 12, in the small auditorium of the Western Society of Engineers, 84 E. Randolph St., Chicago 1. Current trends in film distribution will be dsucussed by Thomas McConnell, Chicago attorney and authority on that phase of the motion picture industry.

This will be a double feature meeting, with a second paper presented by George W. Colburn, describing a Double System 16-mm Projector. Educational and

advertising film producers who work exclusively with 16-mm films should be greatly interested, since Mr. Colburn will describe the modification of a conventional 16-mm projector which enables it to reproduce separate films for picture and sound track.

67th Convention

Plans are well underway for the 67th Society Convention to be held at the Drake Hotel in Chicago, April 24–28th. Members and their guests who plan to attend will be assured of adequate hotel accommodations since many rooms have been set aside by the hotel. These and other arrangements have already been made by Bill Kunzmann, our perennial Convention Vice-President. The Papers Program is already beginning to take form and the Papers Committee is hard at work.

An advance schedule of convention events, with hotel room reservation forms, will be mailed to all members about March 1. The Papers Committee expects to mail, about the last week in March, the Tentative Program listing all papers then scheduled. Authors who expect to present papers should ask the nearest Papers Committee Vice-Chairman for their Author's Forms. Copies of the Author's Form, together with a 100-word abstract of each paper should be sent to R. T. Van Niman in Chicago, so that the paper can be scheduled in time for the Tentative Program.

PAPERS COMMITTEE

N. L. Simmons, *Chairman*
6706 Santa Monica Blvd.,
Hollywood, Calif.

Vice-Chairmen:

J. E. Aiken
116 N. Galveston St., Arlington, Va.

L. D. Grignon
20th Century-Fox Films Corp.,
Beverly Hills, Calif.

E. S. Seeley
Altec Service Corp.,
161 Sixth Ave., New York 13, N.Y.

R. T. Van Niman
4501 Washington Blvd.,
Chicago 24, Ill.

H. S. Walker
1620 Notre Dame St., W.,
Montreal, Que., Canada

The Editor

This month's masthead shows for the first time our new Editor — Vic Allen, who joined us late in November. In previous experience as Production Manager for Interscience Publishers, he put into production Bill Offenhauser's book, *16-Mm Sound Motion Pictures*. He is well acquainted with the Society's printer, Mack Printing Company, in Easton, Pennsylvania, having handled several thousand pages printed yearly by Mack for Interscience. Before joining Interscience, he was Managing Editor of the *Journal* of the American Water Works Association. He began his technical editing on *The Foundry* magazine of Penton Publishing Company in Cleveland while a "co-operative" student from Antioch College. He has contributed to the publishing and printing field by active membership in the American Institute of Graphic Arts and by articles on such subjects as: various methods of typesetting tabular matter; two-column format for technical books; and methods of drafting technical illustrations.

Book Reviews

Acoustic Measurements, by Leo L. Beranek

Published (1949) by John Wiley & Sons, 440 Fourth Ave., New York 16. 896 pp. + 17 pp. index + VII pp. 519 illus. $6 \times 8^3/_4$ in. Price, \$7.00.

This much needed book is a comprehensive collection of techniques and of tables of constants which the acoustic engineer requires for measurements and calculations. Of interest is a brief history of acoustic measuring instruments; and of reference value is a glossary of terminology. Dr. Beranek presents the solutions of the sound wave equations in various forms, with complete data on the velocity and attenuation in a great variety of media including effects of wind, jungle growth, etc.; and he also gives the experimental and calculated diffraction effects due to variously shaped bodies placed in the path of a plane.

Then follows an excellent treatise on techniques of calibrating microphones as standards for measuring sound pressures with particular emphasis on the reciprocity method. The methods generally used for measuring frequency are clearly presented with some good photographs of commercial instruments available

The chapter on the principles of calibrating pure tone audiometers is timely because of current efforts to develop specifications for a standard audiometer. The author discusses various types of meters for measuring quantities related to sound intensity such as peak meters, V. U. meters, level recorders, RMS meters, and also meters for analyzing transient and steady sounds into various sorts of components. The basic tests for the efficiency of communication systems to transmit speech are itemized and described, such as methods of measuring frequency and nonlinear response characteristics, repetition counts, syllable, word, and sentence articulation tests, and threshold measurements of received speech.

Methods are given in detail for testing the three basic elements of a communication system: the microphone, the line (including amplifier), and the headphone or loudspeaker. In each case the author has outlined the method of testing the frequency response, the power efficiency, the impedance, the nonlinear distortion, and overload capacity. With the discussion on loudspeakers there is a useful set of curves for determining power rating to give satisfactory loudness of speech or music in rooms of any size and treatment. There is one chapter on real voice testing methods of determining response characteristics of microphones and earphones. It is shown how these principles can be applied in a convenient form for testing the important characteristics of hearing aids. Methods of making articulation tests are outlined together with lists of syllables, of words, and of sentences, including the P. B. and Spondee tests.

The last three chapters are devoted to measurements of the acoustic properties of rooms, including the various methods of measuring the absorption properties of materials for treatment of such rooms. References throughout the book are numerous and should permit a student to pursue very satisfactorily any special phase. Many engineers will be grateful to Dr. Beranek for bringing together in such a convenient form so much technical information bearing on acoustic measurements.

Harvey Fletcher
(Columbia University)
5 Westminster Rd.
Summit, N.J.

Painting with Light, by John Alton

Published (1949) by Macmillan, 60 Fifth Ave., New York 11. 191 pp. + XIV pp. 292 figs. $7^3/_4 \times 10^1/_4$ in. Price, $6.00.

It has been said that the mechanical techniques of an art should be learned, then forgotten. More properly stated, they should become an unconscious part of the work of an artist. The author of *Painting with Light* frankly describes the techniques and devices he uses to obtain his effects. He does not assume that a novice may become a Director of Photography by reading his book and studying the copious layouts and illustrations, but he does describe his work with a straightforwardness that is refreshing as well as instructive.

While the book may seem to be an oversimplification of a very complicated art form to his brother workers in motion picture photography, it will serve as a means of conveying some of the problems of the cinematographer to many other departments of the industry, as well as to the associated organizations which design and manufacture equipment and materials for the industry.

The motion picture industry has a language of its own for describing the various workers and accoutrements used in motion picture set lighting and the book acts as an interpreter for the uninitiated.

The various types of lamps and lighting control equipment are described and illustrated. Lamp placement and manipulation are explained and illustrated with layouts as well as with photographs of the end results.

Chapters cover both indoor and outdoor photography, the close-up, long-shot, process work, and miniatures. For the most part, the author does not deviate from his subject and, while some of his techniques such as the "testlight" are not universal, he has spared neither time nor expense to cover the subject as completely as possible in so far as black and white photography is concerned, from his own viewpoint and within the covers of one book.

John W. Boyle, A.S.C.
Director of Photography
$139^1/_2$ So. Doheny Drive
Los Angeles 48, Calif.

Feininger on Photography, by Andreas Feininger

Published (1949) by Ziff-Davis, 350 Fifth Ave., New York 1. 409 pp., 360 illus. (approx.), 50 charts (approx.). $8^1/_2 \times 11$ in. Price, $15.00.

It is rare that a reviewer for a technical journal can go all out in praise of a basic book on photography with no fear that he is exposing himself to criticism. But this book is one that even the astute technician will consider well done for the purpose intended.

Mr. Feininger has put down for the amateur and professional still photographer what his 20 years of experience have shown to be essential to good picture making. Although he de-emphasizes matters of a strictly technical nature, he advocates systematic working methods based on fact and not folly. In reading the text one cannot help but be impressed by the unusually clear and, for the most part, accurate, insight into technical matters that the author has gained from his experience. It even appears that he may have studied the better technical literature to a greater extent than he recommends.

The book covers the subject thoroughly in 16 chapters. Little time is wasted anywhere in getting to the point, for the author is no believer in secrets or mystery in the photographic process; but he does stress that technical knowledge alone will never make a good photographer. This requires an "eye" for pictures which you either do or do not have. This attitude explains why Part I on technique consists of but seven chapters, whereas Part II on the art of making a photograph contains nine chapters.

Little would be gained by giving the usual list of chapter headings. The real value in the book will be found only in reading it page by page. It is highly recommended, especially to the motion picture engineer who seldom takes pictures, but who now and then gets the yen to "show up those guys at *Life*." Here's your chance, for Feininger, one of *Life's* most famous and able photographers, has left very little unsaid.

LLOYD E. VARDEN
Pavelle Color Inc.
533 West 57th St.
New York 19

The Complete Projectionist, by R. Howard Cricks

Published (1949) by Odhams Press, 6 Catherine St., London, W.C. 2. 335 pp. + 38 pp., including 14-page index. 209 illus. + tipped-in folded insert. 5 × 7½ in. Price, 10/- post free.

This work, obviously intended as a handbook for British projectionists, covers projection from every angle. By virtue of the fact that the author does cover the entire scope of the craft in 335 pp., comprehensive description of any single phase of projection is necessarily lacking. The numerous tables, charts, and illustrations are extremely well presented and will prove valuable to any projectionist or projection engineer.

Mr. Cricks' inclusion of television and several experimental developments will prove interesting to the craft as a whole. His chapters on projection practices in other than theater locations (process projection, 16-mm projection, etc.) are more descriptive of the job than of the technical operation of the equipment.

Despite the fact that data on equipment, rules, and regulations are necessarily limited to the British, the work will prove an informative addition to the library of any member of the craft.

MERLE CHAMBERLIN
Supervisor of Projection
Metro Goldwyn Mayer Studios
Culver City, Calif.

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Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 30, no. 9, September, 1949

The Garutzo Lens in Motion Picture Photography (p. 320) R. M. Newbold

Eclair Camerette Makes U.S. Debut (p. 321) B. Berg

Source Lighting (p. 324) C. Loring

Teaching Speech with 16-mm Movies (p. 330) R. W. Stanmyre

vol. 30, no. 10, October, 1949

They Do it with Infra-Red! (p. 360) Leigh Allen

The Magic of Montage (p. 361) Herb A. Lightman

Balancing Television Camera Tubes (p. 362) Ralph Lawton

vol. 30, no. 11, November, 1949

Lighting Translucent Backings (p. 398) L. Garmes

Signal System (p. 402) L. Allen

vol. 30, no. 12, December, 1949

New Speed for Films (p. 440) L. Allen

A 16-mm Sound Camera for the Home Movie Maker (p. 444) G. B. Lewis

British Kinematography

vol. 15, no. 2, August, 1949

Developments in Magnetic Sound-on-Film Recording

Pt. I, Magnetic Sound and the Film (p. 37) O. K. Kolb

Pt. II, Magnetic Recording in Film Production (p. 47) N. Leevers

Pt. III, Performance Data of Magnetic Coatings (p. 50) A. Tutchings

Demonstration of Sub-Standard Kinematograph Equipment

Danson Projector D23 (p. 54) W. Lacey

Debrie D16 Projector with Arc Lamp (p. 55) T. A. Bartlett

Long-Running Projector with Mercury Lamp (p. 55) P. J. Oram

M. R. Type 356 Cine-Flash (p. 56) H. K. Bourne

"Brook" Continuous Projector (p. 57) H. S. Hind

vol. 15, no. 3, September, 1949

Closed Sequence Control Systems (p. 75) E. B. Pearson and A. Porter

The Application of Music to Films (p. 86) H. Clifford

vol. 15, no. 4, October, 1949

Thirty Years of British Film Production (p. 105) M. Balcon

Current Practice in 16-mm Sound Printing (p. 116) M. V. Hoare

vol. 15, no. 5, November, 1949

Independent Frame Film Production:

I. Notes on a Production Technique (p. 141) K. Bellman

II. Progress Report on Independent Frame (p. 150) D. Wilson

Screen Illumination with Respect to Optics and Arc Characteristics (p. 155) A. G. Duerdoth

Electronics

vol. 22, no. 12, December, 1949

New Directions in Color Television (p. 66)

Dot Systems of Color Television, Pt. 1 (p. 88) W. Boothroyd

International Photographer

vol. 21, no. 9, September, 1949

Light Can be Packaged (p. 20), A. Wyckoff

International Projectionist

vol. 24, no. 9, September, 1949

Lens and Film Factors Affecting Focus, Pt. 2 (p. 7) R. A. Mitchell

The 'Arcon' Projection Arc Monitor (p. 10) V. G. Mathisen

New Series of Lenses for 16-mm Professional Projection (p. 16) A. E. Neumer

vol. 24, no. 11, November, 1949

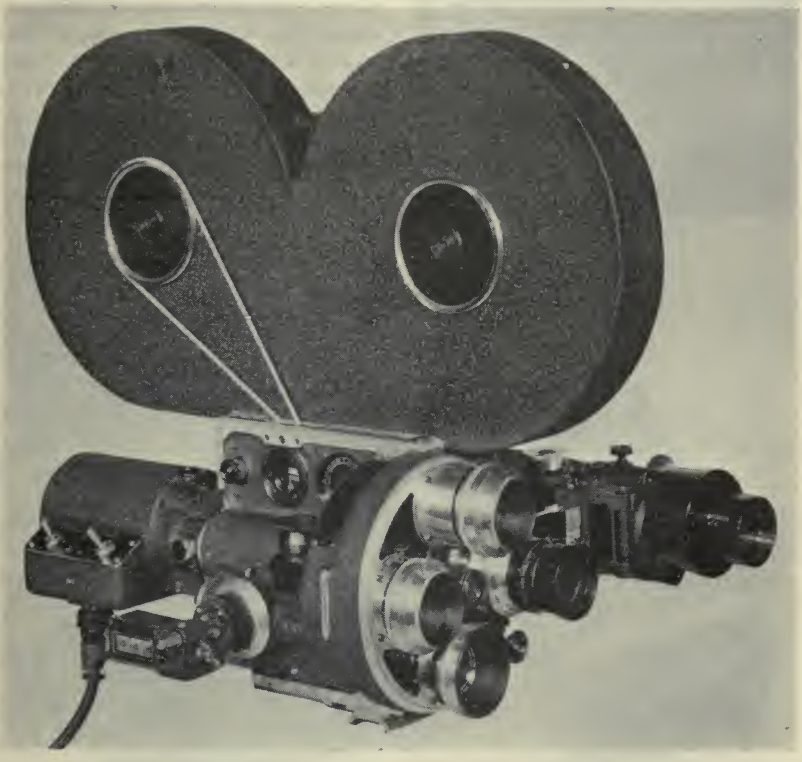
The 35-mm Projection Positive Film (p. 8) R. A. Mitchell

Theatre Television: What, How and When (p. 12) J. E. McCoy and H. P. Warner

Film Fire Characteristics (p. 16) R. D. Marks

New Products

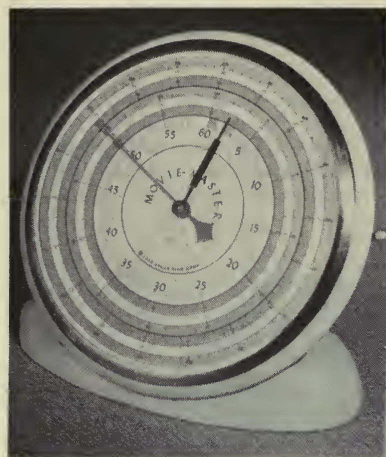
Further information concerning the material described below can be obtained by writing direct to the manufacturers. As in the case of technical papers, publication of these news items does not constitute endorsement of the manufacturer's statements nor of his products.



The Bell & Howell Design 2709 16-mm Camera is B&H's answer to the growing demands of the professional 16-mm field. It is an adaptation of the B&H Design 2709 Standard Camera (35-mm), with these reported features: (1) a 4-lens turret designed to permit the use of all the standard professional lenses; (2) a fixed-pilot-pin film movement mechanism similar to the B&H Unit "I"; (3) a 170° adjustable shutter with automatic dissolve; and (4) adaptability of stop-motion motor for one-, two- or three-frame operation.

The 200-, 400- and 1000-ft standard B&H (35-mm) magazines may be adapted to the 16-mm size by double flanges, rollers and cores.

Information is available from the Professional Equipment Div., Bell & Howell Co., 7100 McCormick Rd., Chicago 45.



The Movie Master is a new timepiece manufactured by Atlas Time Corp., 2 West 47th St., New York 19. A forerunner of the Movie Master timer was the stop watch and timer made by Moss and Robinson, a subsidiary of Atlas Time Corp. The new timer has the same general features: three outer scales dividing the minute into 90 parts; three inner scales dividing the minute into 36 parts; and an extreme inner scale or minute track dividing the minute into 60 sec. It denotes in the first three minutes which of the colored scales of either 35- or 16-mm is in use. It has a $5^1/_2$-in. dial and stands on a table. The price is $12.50.

This Densitometer has been developed by the Photovolt Corp., 95 Madison Ave., New York 16, and is fully described in that firm's Bulletin No. 245. It is a photoelectric instrument designed to cover the transmission density range from 0 to 5.0. The range from 0 to 2.0 is direct reading, while other ranges may be selected by the operator and involve the use of an addition factor.

The densitometer is provided with a traveling film guide that accommodates both 16- and 35-mm film with the sound track always in register with an illuminated slit 0.020 in. wide. It also "reads" Eastman IIb Sensitometer strips and the smaller strips from the Eastman Processing Control Sensitometer, replacing more elaborate and more expensive equipment which in the past has been used for making these measurements on black-and-white films.

The Weston Cadet is a new exposure meter designed especially for travelers and casual photographers who want a small, easy-to-use meter. Its list price is $21.50. It is made by the Weston Electrical Instrument Corp., 617 Frelinghuysen Ave., Newark 5, N.J. Though small enough to fit into a vest pocket or purse, it is equipped with the Weston instrument movement and photronic cell, and is designed to give accurate shutter and diaphragm settings for all general amateur photography with either still or motion picture cameras, and for both black-and-white and color film. The Weston Cadet can be used for measuring incident light by using a translucent light collector which is pivoted on the back of the meter.

Meetings of Other Societies

March, 1950

Institute of Radio Engineers National Convention	March 6 through March 9 New York, New York
Optical Society of America Winter Meeting	March 9 through March 11 New York, New York

May, 1950

Armed Forces Communications Association Annual Meeting	May 12 New York City and Long Island City May 13 Fort Monmouth, New Jersey

June, 1950

Acoustical Society of America	June 22–24 State College, Pennsylvania

SMPTE Officers and Committees: The names of Society Officers and of Committee Chairmen and Members are published annually in the April issue of the Journal. Changes and corrections to these listings are published in the September Journal.

The Blue Comet Boom Light has been developed by Mole-Richardson Co. of Hollywood, Calif., to supply flexible illumination in commercial, motion picture and television studios. A new feature described by the manufacturer is the light-weight Blue Zephyr baby spot, with attached full-size diffusion frame and rotating barn doors, plus direct-action focusing with graduated scale. The lamp head is interchangeable with boom or the included auxiliary stand. To facilitate handling and transporting, the stand and boom legs are designed to fold flat, and the stand is strongly constructed with positive locking fittings and 3-in. rubber-tired casters with locking feet. The stand is reported not to tip even when operated at a y fully extended position, and the stand and boom arm are designed for easy extension, with an air-retainer brake in the boom stand to permit smooth, quiet adjustment of height.

SMPTE HONOR ROLL

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased.

Louis Aimé Augustin Le Prince
William Friese-Greene
Thomas Alva Edison
George Eastman
Frederic Eugene Ives
Jean Acme Le Roy
C. Francis Jenkins
Eugene Augustin Lauste
William Kennedy Laurie Dickson
Edwin Stanton Porter
Herman A. DeVry
Robert W. Paul
Frank H. Richardson
Leon Gaumont
Theodore W. Case
Edward B. Craft
Samuel L. Warner
Louis Lumiere
Thomas Armat

HONORARY MEMBERS

Lee de Forest
A. S. Howell

Journal of the Society of
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Basic Research For Motion Pictures

By CLYDE R. KEITH

SMPTE Editorial Vice-President

It has been pointed out many times that engineering progress depends directly on basic research. Engineering is largely the application of scientific principles to the solution of practical problems. When new basic principles are discovered, engineering skill rapidly transforms these new ideas into things of value to both industry and consumer in the form of better or cheaper products. But when the available fund of basic information has been worked over for twenty years or more, the engineering "advances" are very apt to be reduced to gadgets, fancy knobs, and other trimmings which are of little real value even from a sales standpoint.

The motion picture industry has for the most part left basic research to the various suppliers of film and equipment. Some remarkable improvements have come out of these industrial research laboratories, but it is only natural that their research should be aimed at results which will assist the commercial operations of the particular company operating such a laboratory.

There are some subjects of vital interest to the motion picture industry which are not directly related to any commercial product and therefore have not been the subject of research to the extent employed in connection with directly salable products. Some such subjects are various physio-psychological effects on motion picture theater patrons. The effect of physical factors of the projected picture on eyestrain and fatigue is one, and the effects of various forms of illumination around the screen on the psychological reaction to the picture is another.

It is obvious that basic research is slow and expensive, and cannot be expected to show immediate returns in cash or any other tangible manner. Certainly the SMPTE could not set up a research laboratory for the study of such problems, although it is interested in such research and would like to encourage it in any way possible.

Some of the older members no doubt recall that in the early 30's the Society did sponsor basic study on a fundamental problem. A Fellowship was awarded to Mr. Peter A. Snell for graduate study at the Institute of Applied Optics, University of Rochester. Mr. Snell studied visual fatigue in viewing motion pictures, an account of this study being published in the May, 1933, issue of the JOURNAL. While Mr. Snell made an excellent contribution to knowledge on this subject, the possibilities along this line were not exhausted, and that was over sixteen years ago.

Here seems to be a way in which the SMPTE can be of definite service to the industry. There must be numerous candidates for advanced degrees in physics at various universities, some of whom might be glad to devote their research to a subject relating to the physical and psychological aspects of vision. A list of proposed research projects prepared by the SMPTE might be instrumental in influencing a graduate student to undertake such work. The establishment of some form of fellowship or honorarium for the research worker would no doubt also help.

The views of Society members on this subject will be welcomed.

Noise Considerations in Sound-Recording Transmission Systems

By F. L. Hopper

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Summary—**Noise limitations in sound-recording media are well known. With improved media such as magnetic materials, noise limitations imposed by the recording transmission system require consideration. Noise may be internally generated in the system or may be introduced from extraneous sources by electromagnetic coupling, or circuit exposures to interfering fields. Radio and audio frequency disturbances, crosstalk, thermal noise, shot-effect, microphonics, and alternating current hum are some of the interferences considered.**

The inherent noise limitations of various forms of recording media have been the subject of considerable study. The most commonly used materials in the past have been various types of disk records and photographic film. Unmodulated background noise in these materials is such that the available dynamic volume range between noise and a maximum signal whose distortion is on the order of 2% is 30 to 40 db. This basic volume range has of course been effectively increased by use of such recording methods as: pre- and post-equalization, volume compression and expansion, dynamic noise suppressors which vary the bandwidth of the reproduced signal, and noise reduction devices as applied to photographic recording. The introduction of magnetically coated film has provided a medium capable of accommodating a volume range of some 60 db without recourse to complex electronic devices. With such an improvement in signal-to-noise ratio, noise limitations imposed by the recording transmission system require consideration in order that they may not become a limiting factor in over-all system performance. Noise may be internally generated in the transmission system, or may be introduced from extraneous sources by electromagnetic coupling, or may enter the system conductively, through circuit exposures to interfering fields. This paper will consider various types of externally and in-

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ternally generated noise disturbances, which may seriously reduce the effective volume range of the recording media. It is of course recognized that there is an ultimate minimum of noise which cannot be reduced by any practical means, but it is the engineer's desire to approximate this limit. The various types of noise interference may be classified as outlined below.

I. Noise Sources External to the System

A. Radio Frequency Noise

Disturbances due to radio frequencies entering the system are generally troublesome only when the signal is a modulated radio carrier. Subsequent demodulation in the system due to various factors may result in an audio frequency signal. Methods for correction may require magnetic shielding or the use of circuit elements to provide a filtering action.

This type of disturbance may also be introduced into the transmission system due to exposure of connecting circuits to interfering fields. Power connections to a-c mains, long microphone cables, or even the ground connection itself, may introduce such interference.

Corrective measures depending upon the type of exposure may include the following:

1. Use of magnetic shields[1,2,3,4] in low-level audio stages on transformers and vacuum tubes.

2. Shielding of grid and grid return circuits in copper braid-shielded wire.

3. Radio frequency filtering utilizing a small series choke coil of a few millihenrys inductance in the grid circuit as close as possible to the grid connection of the tube itself. A by-pass condenser of some 100 micromicrofarads capacity connected from grid to ground may also be effective. Possible deterioration of the audio frequency response of the apparatus should be measured, when such filtering is added.

4. Careful shielding of long connecting circuits such as microphone cables using a braided copper shield which is insulated from contact with the earth.

5. Use of an electrostatically shielded transformer as a barrier between the primary power source and the system rectifiers.

B. Audio Frequency Noise

Audio frequency noises introduced by means of electric or magnetic induction are apt to consist principally of power line frequency or its multiples. In general, remedial measures are: increased physical separation between the source of disturbance and the affected apparatus; or the use of magnetic shields on either or both of the disturbing or affected equipment components.

Audio frequency noise components introduced into the system via connecting external wires may also consist of power line frequency or its multiples. Use of transposed or twisted conductors is an effective means of reducing such interference. Such twisted conductors cause both sides of the circuit to be equally exposed to the interfering field, and the induced currents largely cancel. Magnetic shielding of such conductors is ineffective unless such magnetic materials as iron pipe or flexible conduit are used. Most effective, but seldom used, is a permalloy wrap similar to that used for continuous loading of submarine cable.

Crosstalk may prove to be an undesirable source of interference and may be caused by: an inductive field, a shunt admittance or series impedance, or by a common impedance.

In addition to shielding, crosstalk may be reduced by using transposed or twisted transmission pairs. The twist, to have maximum effect, should be completely uniform, a condition which generally obtains when each wire of the pair is of equal length. If the interfering induction field affects all parts of the circuit with equal intensity only a loose twist is required. If all parts are not affected with equal intensity, a tight twist is indicated. For example, if the crosstalk occurs between adjacent pairs in a cable or form, since the cable is probably short in comparison with the wavelength of the interfering induction noise, only one transposition is theoretically required since each half of the circuit is equally exposed. If, however, the circuit being interfered with passes near a point source of interference, the intensity of the field will diminish as the square of the distance from the point. In such a case there should be an infinite number of twists per unit length to annul completely the interfering field. The principal consideration is that both sides of the circuit must have exactly equal exposure to the interfering field. It must be realized that the induced currents on each wire of the pair, although they may be exactly equal in amplitude and opposite in phase, cannot cancel

until the currents flow into a common junction. At this point, which should be grounded, complete cancellation results only if the currents are exactly equal and in phase opposition.

Both balanced and unbalanced types of transmission systems are in common use. Balanced-to-ground transmission has been found by far the most practical when circuits are long and is useful when the circuits are of the order of 20 ft in length. However, expensive coils and more complicated components are required. Unbalanced circuits require less complicated components but because of the unavoidable unequal series impedance they are more susceptible to inductive effects. The best results will be obtained from either type of transmission when proper attention is given to grounding. The choice of type of transmission system can be made only after carefully weighing the economies of the unbalanced method against the higher protection factor of the balanced method.

Level differences in cables and wiring forms should be kept to within a reasonable figure. A well-shielded cable form can tolerate level differences exceeding 60 db between conductors if the form is not longer than 10 ft. This requires intelligent shielding and circuit geometry. Under these conditions the crosstalk may be 60 db or more down from average signal levels when unbalanced transmission is used and considerably more when balanced transmission is used. Differences in level in cable forms of 60 db or greater should be tolerated only if it is a local condition as in the case of equipment within a rack or console. Interconnecting circuits between racks should be kept physically separated, in separate conduits if possible, when level differences are 60 db or greater, or when both balanced and unbalanced circuits are in the same cable forms. The individual pairs of these cable forms should have separate copper braid shields and the braided shields themselves should be insulated from each other. When crosstalk occurs in a cable form despite all precautions it is often found that by selecting pairs the effect can be reduced to a tolerable level. This also applies to lead cable. If the crosstalk occurs between circuits, one or both of which is unbalanced, the only effective remedy, outside of increased physical separation, may consist in balancing the circuit by means of a repeating coil. If unbalanced transmission must be restored as the circuit pair leaves the form, two coils may be required. If the crosstalk is not severe, an elaborately balanced coil will not be required. When exploring for crosstalk a relatively high frequency should be used, since crosstalk

is more apparent at these frequencies. Circuit irregularities are sometimes such that a narrow region of crosstalk occurs and perhaps a thousand cycles or so on each side of this region the crosstalk is not detectable. It is usually good practice to short-circuit or ground all unused pairs in a cable form.

II. NOISE ORIGINATING WITHIN THE SYSTEM

A. *Thermal Agitation Noise*

The current in the output of an amplifier due to the thermal agitation noise in a resistance R connected to the input terminals of the amplifier is[5]:

$$\bar{I}^2 = \frac{2KT}{\pi}\int_0^\infty R(\omega)\,|Y(\omega)|^2\,d\omega$$

where I = current in output of amplifier
$R(\omega)$ = resistance connected to input of amplifier
$Y(\omega)$ = transfer admittance of amplifier = I/V
V = voltage required across amplifier input terminals to cause a current = I to flow in the output
$\omega = 2\pi f$
T = degrees Kelvin
K = Boltzmann's gas constant = 1.37×10^{-16} joules per degree.

If R is independent of frequency, usually a valid assumption over the audio frequency range, and if the amplifier is flat over the audio band from f_1 to f_2 and has zero gain outside of these limits, the above equation becomes:

$$V^2 = 4KTR\,(f_2 - f_1).$$

This voltage V, is that voltage of any frequency between f_2 and f_1 which, if applied to the input of the amplifier, would cause a current I to flow in the output of the same magnitude as does the thermal agitation noise in R. Putting T = 300 K (80.6 F), letting $(f_2 - f_1)$ equal 15,000 cycles, the equation becomes:

$$V^2 = 2.46 \times 10^{-16}\,R.$$

The voltage squared in the above equation is, however, the open circuit voltage across the resistance R. It can be shown that the conditions under which the amplifier operates are such that the resistance R is actually terminated in its own impedance which reduces

the thermal agitation voltage by a factor of 2^2 or 4. V^2 then becomes

$$V^2 = \frac{2.46 \times 10^{-16} R}{4}$$

$$V^2 = .615 \times 10^{-16} R$$

and $$V^2/R = .615 \times 10^{-16} \text{ watts.}$$

From this it can be seen that the thermal agitation noise is a constant power of -132 dbm (under the conditions prescribed above) and that the voltage consequent to this power is determined by the resistance alone. The amplifier should be visualized as an ideal transformer terminated on its primary with the generator resistance R, and on its secondary by the load resistance of the external circuit. The load resistance divided by the impedance ratio of the ideal transformer presents a termination to the generator resistance equal to itself. The open circuit thermal agitation voltage is consequently reduced to one half.

If the internal impedance of the amplifier is very high with respect to the generator impedance a justified assumption is that all of the thermal agitation noise in the output comes from the generator. The noise in the output, provided the amplifier is designed so that there is no contribution of noise from the input tube, will then be -132 dbm plus the gain of the amplifier.

The noise due to thermal agitation is irreducible by any practical expedient. Any noise originating at points subsequent to the grid of the first tube represents an addition to this noise without a corresponding increase in signal. The limit to be attained[6] in signal-to-noise ratio is therefore the ratio of the input signal to the thermal noise of the input circuit.

B. Shot-Effect and Other Tube Noise

Shot-effect[7] is due to the fact that the electron flow to the anode of a vacuum tube is not of uniform density. Space charge in vacuum tubes creates a cushioning effect which reduces the shot noise by increasing the uniformity of electron flow. Theoretically, in the case of complete temperature saturation, the space charge would reduce shot-effect to zero. Practically, this condition obtains in vacuum tubes used in most amplifiers. Formulas exist[8] which allow accurate calculation of shot-effect both in the presence and absence of space charge.

The major noise contribution by the vacuum tube is the internal thermal agitation noise.[9] This occurs in the plate circuit. In amplifier design work it is important to evaluate this noise so that the first amplifier stage will sufficiently amplify the input thermal noise to override the thermal noise of the tube itself. If this course is followed the tube contributes little noise to the circuit. The thermal noise arising in the tube comes from the cathode-to-plate resistance within the tube itself. It is the same in all respects as thermal noise generated in a resistor but it is important to remember that the temperature of the plate resistance is that of the cathode. In modern tubes this temperature is of the order of 1000 to 2000 K. Because the plate resistance appears in shunt with the external plate load resistance, the total effect must be considered to be that of two independent generators in parallel. Formulas for calculating this noise are fully explained elsewhere.[8]

There are other sources of noise within a vacuum tube due to flicker effect, collision ionization, secondary emission, positive ion noise, and noise which may be generalized under the heading of microphonics. Except for the latter, which is a primary noise factor under certain conditions, the noise contribution by such secondary effects is negligible.

The gong-like sound of microphonic noise[10] is familiar. Tubes may be designed to minimize these effects, but in any case may require selection. Other means of reducing microphonics include shock mountings where the period of the tube and socket assembly is increased to reduce susceptibility to external mechanical shock; or if the shock is airborne, surrounding the tube with an acoustic shield. Another type of noise which is classed under the heading of microphonic noise is termed "sputter noise." This noise arises due to mechanical support problems of the tube elements and internal insulation leaks. Some types of sputter noise, such as those affected by element support considerations, are only apparent in conjunction with the usual microphonic noise and will be eliminated or reduced by the same methods which reduce microphonics. The other type, due to insulation leakage, may appear independently and since this is a tube manufacturing problem the engineer can only select tubes free from this noise.

Noise originating in vacuum tubes is often considered, from an amplifier design standpoint, to be equivalent to a thermal noise generated in a fictitious resistance[8] in the input. While tube noise has a

frequency characteristic, and thermal noise has none, the convenience of the assumption outweighs the defect in the analogy. This fictitious resistance called the "equivalent noise input resistance" is measured as follows.[11] Assume that a resistance equivalent to the internal resistance of a generator, such as a microphone, is connected through a suitable transformer to the grid of a vacuum tube. The thermal noise arising in the resistance will be amplified by the tube in the normal way. This noise represents the lowest possible noise in a system of given frequency response. The tube also generates noise within itself which adds to the external thermal noise. Maximum signal-to-noise ratio can be achieved only when tube noise is negligible as compared to thermal noise. If the grid of the tube is grounded and the external equivalent generator resistance and coupling transformer are disconnected, the noise currents remaining in the output of the tube will be due to the tube itself. This noise is measured by a voltmeter or thermocouple having square law characteristics. Additional amplification in conjunction with the meter will be required. If the short circuit from grid to ground is removed and a resistor placed across the same points, a value of resistance will be found which, due to its thermal noise output, will exactly double the meter deflection (or raise it 3 db). This is an indication that the thermal noise generated by the resistor is equal to the noise generated by the tube. The value of the resistance is called the "equivalent noise input resistance" (R_{eni}) of the tube. The R_{eni} of tubes can be calculated and formulas are available for triodes, pentodes, triode and pentode mixers and multigrid converters.

Tubes showing extremely low values of R_{eni} do so by virtue of a high transconductance usually obtained by close grid-to-cathode spacing. Consequently there are other considerations, such as microphonic characteristics, stability of performance, and low hum disturbance factor, in selecting a tube for audio pre-amplifier use.

C. *Fluctuation Noise in Granular Type Resistance Carrying Direct Current*

When direct current is passed through carbon resistors which are granular in nature or through resistors consisting of sputtered or evaporated metal films, small voltage fluctuations appear across the resistor terminals. This adds to the basic noise of the system and any attempt to reduce the basic noise to as low a value as possible must take this into consideration. This has been termed contact noise and

the hypothesis advanced[12] is that it is due to minute resistance variations in the region of contact between the granular boundaries. As would be expected the expression for the generated voltage is complicated. The voltage depends upon the value of the resistance, the direct-current voltage across the resistance, the frequency range, and two empirically determined exponents and a constant. The distribution of noise with frequency shows an increase in noise energy with decreasing frequency at the rate of 3 db per octave.

D. Hum Noise Due to A-C Operation of Filaments

The use of indirectly heated unipotential cathodes removes most of the factors which produce hum[13] in vacuum tubes when operated from an alternating-current source. Due to the almost universal use of heater-type cathodes no consideration of filamentary cathodes will be discussed. Hum is due to (1) the magnetic field produced by the heater current; (2) leakage resistance from heater to other electrodes; (3) electrostatic fields due to lack of complete heater shielding; and (4) electron emission from the heater.

The magnetic field creates a double-frequency hum. The problem is one which must be dealt with in tube manufacture. Remedial measures consist in "twisting" the heater wires or other such methods of obtaining essentially noninductive heaters, high-voltage-low-current heater operation and certain modifications of the tube geometry.

Leakage resistance from heater to other electrodes is often due to "getter" deposits within the tube. This type of hum can be reduced by lowering the impedance of the affected electrode to ground. Another method, when leakage exists between heater and cathode, is to bias the heater either positive or negative with respect to the cathode. A ± 10-volt bias is almost always adequate and little difference is usually found between a positive or negative bias.

Hum due to capacitive coupling is of fundamental power main frequency. The most objectionable capacity is that which exists between heater and control grid. The effect of this capacity is reduced by lowering the grid-to-ground impedance which is another reason that the secondary impedance of an input transformer should be kept as low as possible. A "bucking-out" potentiometer is sometimes used. This consists of a potentiometer of several hundred ohms connected across the heater leads, the potentiometer swinger being connected to the grid-return lead.

Hum due to heater emission can occur when any electrode is at higher potential than the heater. The situation is sometimes aggravated by some of the cathode coating (barium and strontium oxides for example) getting on the heater during tube manufacture. The work function of the emitting surface of the heater for emission currents can thereby be greatly reduced. The solution most employed is to bias the heater positive with respect to the affected element, usually the cathode. Ordinarily a volt or two is adequate. In rare instances the emission may be from cathode to heater in which case a negative bias is required.

Referring specifically to magnetic recording, since it is necessary in reproduction to employ equalization at low frequencies at a rate of 6 db per octave, in order to achieve uniform over-all frequency response, low frequency noise disturbances assume considerably greater importance. For example, if some 25 db of equalization at 50 to 60 cycles is required for flat response, any fundamental power line frequency disturbance must be reduced by such an amount, if signal-to-noise ratio is to be maintained.

Noise interferences causing the greatest difficulty are:

(1) Introduction of power line fundamental or multiples thereof, by magnetic coupling to apparatus components; (2) introduction of power line frequency or multiples by power wiring to exposed component or interconnecting wiring; and (3) internally generated power line multiples due to a-c operation of vacuum tube heaters.

Corrective measures as indicated in previous sections of this paper will include: use of magnetic shields on both the interfering apparatus element and the equipment component receiving the interference; use of shielded and twisted wire pairs both in internal and interconnecting wiring; and possible recourse to rectified alternating current or use of direct current on the heater elements of vacuum tubes in low-level amplifier stages.

Other described forms of interference are probably no more severe with magnetic systems than those using a photographic medium.

In systems designed with the described noise factors in mind, it will generally be possible to fully achieve the signal-to-noise possibilities inherent in the chosen recording medium.

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Photography in the Rocket-Test Program

By CARLOS H. ELMER

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Summary— **The vast bulk of information gained during a rocket or guided-missile test firing at Inyokern is obtained photographically. This type of detailed recording requires a large number of specialized photographic instruments of various types. They include cinetheodolites, ribbon-frame cameras, high-speed motion picture cameras, and others. The importance of color in this program is described, together with some of the difficult problems that are encountered when combining color film with the high shutter speeds necessary to stop the motion of fast-moving test objects. Some solutions to these problems of underexposure are mentioned.**

The primary function of the United States Naval Ordnance Test Station is the development and testing of weapons, particularly those in the fields of rockets and guided missiles. Located west of Death Valley in California's Mohave Desert, the 800-square-mile expanse of desert and mountains that contains the principal test ranges was selected not only for its isolation but also for its excellent seeing conditions, for the vast bulk of information obtained from these test firings is photographic in nature.

While many of our photographic problems remain unsolved, we feel that we have come a long way since those hectic wartime days when scientists and technicians from the California Institute of Technology first pitched camp on the desert sands and commenced firing rockets from crude launchers. Those pioneers came armed with only a few well-worn Eyemo and Bell and Howell Superspeed cameras as their means of securing information on the test firings, but they developed many of the basic principles of ballistics photography as it is practiced today on our numerous, well-instrumented testing ranges. That early type of photographic coverage served only as a more permanent record of the same information obtained visually by the observers; now an amazing variety of specialized instruments furnish precise numbers denoting velocity, acceleration,

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range, altitude, spin rate, and other data that are the basis of any scientific evaluation and improvement program.

One of the most valuable of these specialized instruments is the cinetheodolite, recording missile position against time in a network that permits the computation of accurate trajectories of flight. At Inyokern, the basic cinetheodolite is the German Askania Kth 41, as modified. This instrument operates at 2 or 4 frames per second, producing double-frame 35-mm pictures on Ansco Color motion picture film. Color film has been found to be the most suitable means of

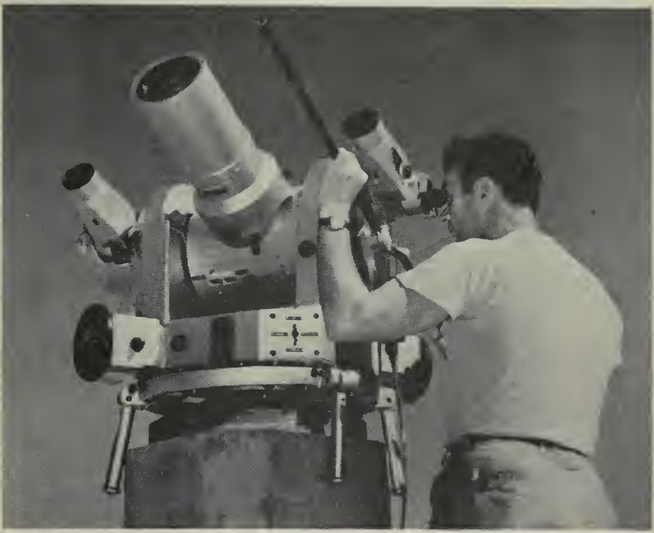

Fig. 1. Askania Cinetheodolite used for guided missile instrumentation at Naval Ordnance Test Station. These instruments have been modified as shown to permit one-man tracking of high-speed missiles.

obtaining easily assessable contrast between painted rockets and the blue-sky background. The Askania theodolite has been improved at Inyokern to permit free-wheeling single-operator tracking in place of two-man geared tracking to permit fast-moving test objects to be followed. Since high-tracking rates resulted in blurred images of the azimuth and elevation dials, the shutters exposing these dials have been removed and replaced by gaseous-discharge lamps, which effectively "freeze" the dial motion. Work has also been done to achieve more effective synchronism of the several instruments in use than was possible with the original equipment.

The Bowen Ribbon-Frame Camera, described in detail by Green and Obst,* is a precision nontracking camera capable of providing extremely accurate metric data on $5^1/_2$-inch aerial roll film at rates of from 30 to 180 frames per second. It is a valuable supplement to the Askania theodolite, especially during the early portions of flights through burning time.

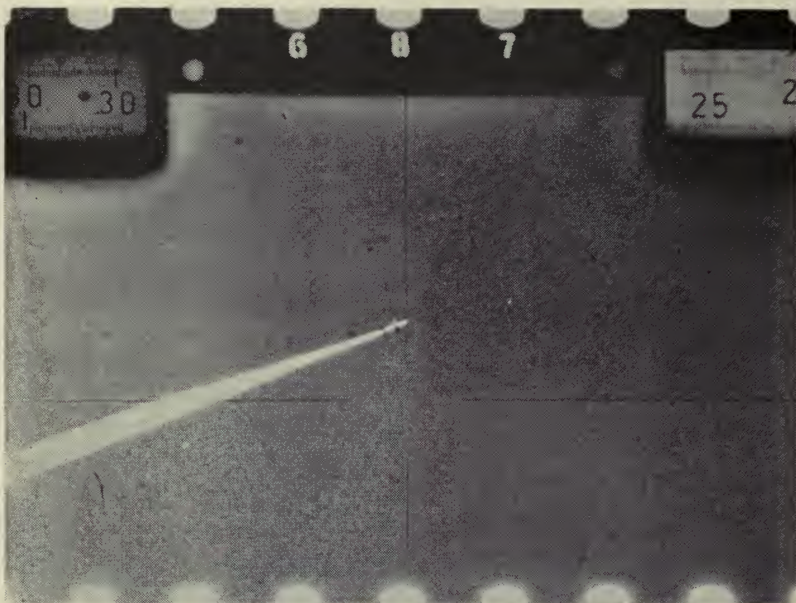

Fig. 2. Typical sample of record obtained by Askania Cinetheodolites. At the top of the frame are, from left to right, azimuth scale, frame number, and elevation scale.

Thirty-five-millimeter Mitchell cameras are operated at speeds up to 120 frames per second to provide information on roll, pitch, yaw, separation of booster from missile, and off-range deflection. The addition of a second lens and shutter into the side of the camera case has converted these cameras into so-called "chronographs." This auxiliary camera system photographs the image of a stop watch on the corner of each frame of film, permitting the assessment of the action photographed to the nearest $^1/_{100}$ second. Forty-inch lenses are most commonly used with these cameras, which are operated

* See pp. 515–23, November, 1949, *Jour. SMPE.*

from conventional tripods or from powered tracking mounts. As in the case of the Askania theodolites, Ansco Color film is used in this camera on most firings.

To obtain detailed slow-motion studies of launchings, separations, static firings, or detonations, extensive use is made of 16- and 35-mm high-speed motion picture cameras operating at speeds up to 4000

Fig. 3. The Bowen Ribbon Frame Camera can be accurately aligned to photograph an expected rocket or missile trajectory. The camera operates at from 30 to 180 frames per second, recording on $5^1/_2$-in. aerial roll film.

frames per second. Some success has been achieved at Inyokern using color film at speeds up to 500 frames per second, because of the brightness level usually encountered on the test ranges which are located on alkaline dry-lake beds.

These and other optical methods of obtaining direct photographic data of test firings are no more important, however, than the indirect photographic records obtained electronically. Recording cameras

photograph oscilloscope tubes, record magnetic pickup traces, and, as oscillographs, receive vital telemetering data from the test objects themselves. Their operation adds to the thousands of feet of motion picture film, wide film, and wide paper which is expended to obtain detailed recordings of a single flight that might last only a few seconds.

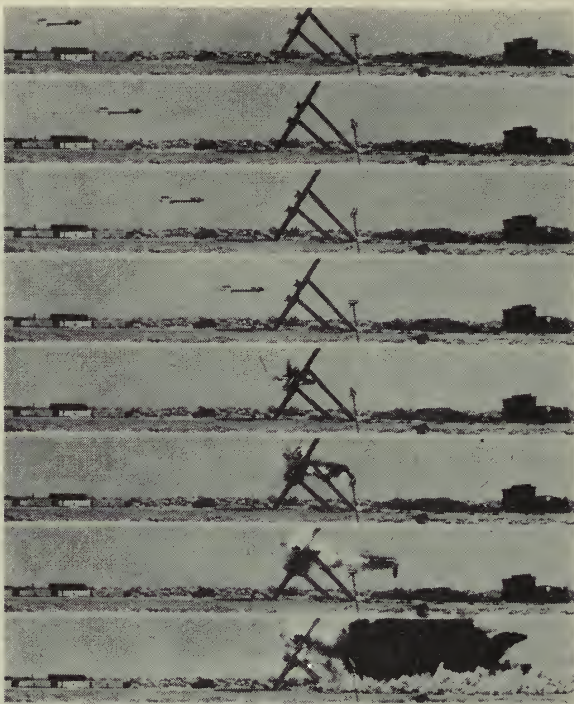

Fig. 4. Typical sample of record obtained by Bowen Ribbon Frame Cameras. This record shows an 11.75-in. aircraft rocket striking and penetrating an armor plate target with resultant high order detonation.

Less quantitative but no less valuable information is secured by "newsreel" photographers who obtain 16-mm Kodachrome records of the assembly and checkout of missiles, their placement on the launchers, their flights, and the state of their remains, when found. This coverage is supplemented by remotely controlled 4- × 5-inch still cameras which obtain Ektachrome photographs of missiles as they just clear the launchers during firing.

Fig. 5. Mitchell Chronograph 35-mm Tracking Camera with 18-in. lens used at Naval Ordnance Test Station to determine missile attitude, roll, and separation information.

Fig. 6. Typical sample of film obtained by 35-mm Mitchell Chronograph camera. Stop watch image is recorded in corner of each frame.

The Naval Ordnance Test Station conducts extensive work in the field of airborne rocket firings and underwater ordnance studies which supplement the firings performed on the ground ballistics ranges. At Inyokern many interesting adaptations of camera equipment have been made to obtain data on firings made from planes in flight against ground targets, while the Underwater Ordnance technicians in Pasadena are busy developing totally new techniques of high-speed underwater illumination and photography.

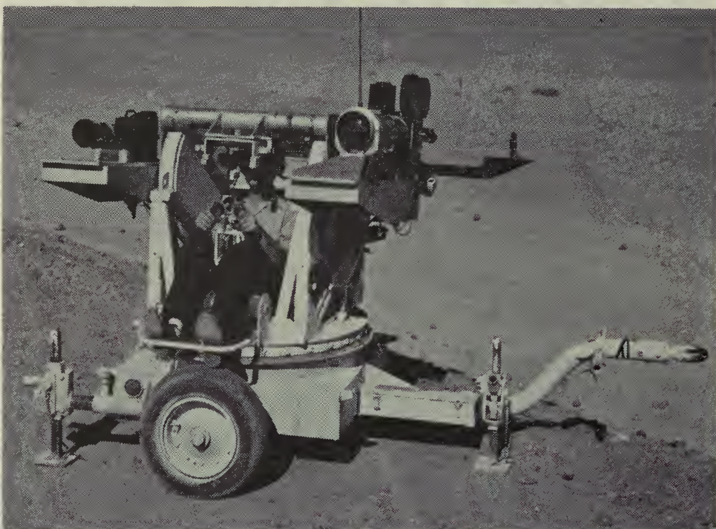

Fig. 7. This MK 45 powered tracking mount carries a 16-mm Eastman High Speed Camera with 20-in. lens and a 35-mm Mitchell Chronograph Camera with 40-in. lens.

The photographic operations on the ranges and in the research laboratories funnel into the Photographic Laboratory Section, which operates an 8000-square-foot production laboratory in one wing of the huge new Michelson Laboratory. While the amount of footage involved is not large by commercial laboratory standards, the lengths of film handled are just as valuable as those shot on a big production scene in an epic Hollywood film. This film is strictly a one-take affair—there are no retakes. An atmosphere of urgency is ever present in the processing laboratories; frequently the test conductor is standing by to see the first round's records before proceeding with the day's firing schedule. Yet the film must be handled with the extreme

care required to produce records that can be minutely assessed under powerful magnification to deliver metric data.

The use of color film in the rocket instrumentation program presents several difficulties. Long focal-length lenses are usually required to photograph distant objects in space or to photograph objects on the ground from safe distances. Such lenses are usually rather slow, and high shutter speeds must be used to freeze the motion of supersonic missiles. This combination of factors usually means severe

Fig. 8. Two 16-mm Eastman High Speed Cameras are aligned to cover the launching of a guided missile. The radio receiver at left receives a broadcast 1000-cycle note and transmits it to timing lamps in the cameras.

underexposure when a film with an American Standards Association rating of 10 is used. Therefore, the Photographic Laboratory has devoted considerable study to methods of effectively raising the emulsion speed of material such as Ansco Color Type 235 motion picture film and Ektachrome cut film. Efforts to date have been confined to a juggling of recommended developing times, although it is realized that several other methods are available for investigation. At present, we obtain normal Ektachrome transparencies exposed at $f/2.5$, $^1/_{800}$ second, by increasing the first developer time from 15 to

20 minutes. Much of the Mitchell Chronograph Ansco Color motion picture film is exposed at $f/8.0$, $^1/_{384}$ second. We have increased Ansco Color first developer time to as much as 33 min and have also juggled color development times. These deviations in processing times do not appear to have caused marked changes in color balance, although color fidelity is not of great concern in our case.

Rocket photography at Inyokern has indeed come a long way since those pioneering days of the California Institute of Technology. Yet, we feel that we are only beginning to learn the science of ballistics photography. As missiles become faster and go farther, instrumentation difficulties multiply, and it becomes evident that much remains unknown and untried. As workers in the program of our nation's defense, we appreciate the valuable assistance and advice given us by the Society of Motion Picture Engineers as we attempt to add to the sum of knowledge in our still infant field of specialized photographic endeavor.

High-Speed Processing of 35-Mm Pictures

By CLIFTON M. TUTTLE AND FORDYCE M. BROWN

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Summary—A piece of apparatus is described by means of which it is possible to develop, fix, wash, and dry pictures on 35-mm film in four seconds. Integral with the apparatus is a camera lens with which the pictures are formed and a projection system with which they are projected. Though the particular device has been designed for radar photography, it is believed to have a variety of other uses and applications.

THE TITLE of this paper may be misleading to the motion picture engineer for whom the concept of speed of processing is based upon the idea of feet of film per minute. The system we are about to describe—in its simplest form—is capable of only a small footage output per unit of time. This output of approximately one foot of 35-mm film per minute would be regarded as extremely slow by those engaged in the quantity production of release prints.

The system and equipment are, in another sense, capable of the highest speed of photographic processing with which the authors are acquainted. In this narrower sense, we refer to the time lapse occurring between the instant when a silver halide-gelatin latent image is subjected to the necessary treatment, and the final production of a usable silver image. Regarding this silver image, we impose some arbitrary qualitative specifications: that it shall be free from undissolved silver halide, meaning that it shall be completely "fixed"; that it shall be permanent, meaning that the products of chemical action tending to produce image deterioration shall be absent; that it shall be dry, and that its over-all quality, as defined by density, contrast, inertia speed, uniformity, and maximum density, shall be favorably comparable to results achievable by conventional processing.

Neither the demand for developments in this field of maximum, rapid processing nor the efforts in cutting down processing time have been lacking. Portraits "while you wait" have been available at county fairs since 1910. Better portraits while you wait a shorter

A CONTRIBUTION: Submitted November 16, 1949.

time are sold by the Photomaton. The Land–Polaroid system requires the shortest wait and gives the best of results in the hands of the amateur. These developments have reduced processing and drying time to the order of one minute.

During the latter part of the War, the demand for quick processing of radar image pictures was met by the Eastman Kodak Co. which produced a unit that photographed the radar screen quickly, processed the image, and projected it onto a screen. The image was made on

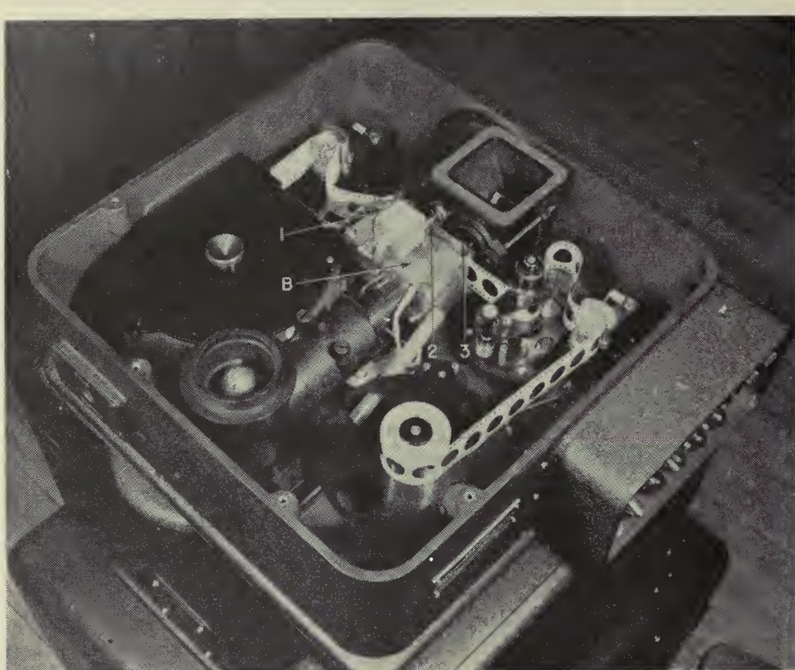

Fig. 1. Photograph showing film path through the apparatus.

16-mm film and occupied an area equal to the largest circle that could be inscribed in a single 16-mm frame. Only a small portion of the total film area was used. The image appeared on every fifth frame and the equipment was capable of producing complete pictures at 13.5-sec intervals. A projected picture, seven feet in diameter, of the Plan Position Indicator Radar Scope was the end result.

The cycle time of this unit made it possible to keep up with 4 rpm radar. The picture size, definition, and brightness were adequate to

resolve and present all of the data shown on the radar set which the photographic unit was designed to complement.

Advances in radar techniques have resulted in higher scanning rates and higher orders of data resolution. The requirements, therefore, for the associated photographic equipment have, as a result, been made more difficult. Scanning rates of 15 rpm demand a processing time of four seconds. Resolving power and other considerations require a 10-ft diameter picture of higher brightness than that produced formerly.

The apparatus we are about to describe has been developed to meet the new requirements and also to meet them in push-button control manner such that one entirely unacquainted with photographic techniques can operate the device.

DESCRIPTION OF APPARATUS

Thirty-five-mm perforated film is used in the apparatus. Figure 1 is a plan view of the film path. This film is fed from a 400-ft retort, past a picture taking station (1), a processing station (2), a projection station (3), over an intermittent sprocket, and onto a take-up reel. The block labeled B in Fig. 1 performs a multiplicity of functions and since it is the heart of the system it is deserving of some detailed description.

Figure 2 is a section of this block, drawn out of scale to illustrate some of the unique principles of this quick photography method.

First position: The film (1), shown edgewise, passes first the latent image forming position (2), where the optical image, 0.700 in. in diameter, is brought to focus on the emulsion through the transparent base. At the end of the exposure period, the film is advanced the distance of five standard perforations (0.935 in.) to the processing position (3).

Second position: Within 2 milliseconds of its advance, a vacuum of about 4 in. of mercury is applied through an annular ring (4). This vacuum causes the film to be sucked inward (downward in the figure), resulting in the formation of a paraboloidal surface convex toward the emulsion side of the film. Matching this emulsion surface but removed from it by 0.005 in. is a polished stainless steel surface (5). The two surfaces—emulsion and steel—form the boundaries of a parabolic shell. The vacuum is formed and the film is sucked inward only when a poppet valve (6) is opened.

Now, when a second valve (7) is opened, a solution piped through the tube (8) is sucked through the central orifice (9). Under the influence of the vacuum, a chemical solution passes with high and nearly constant velocity of 18 cms/sec, radially across the film surface and out the annular aperture (4).

Important to the achievement of fast and uniform development, fixation, washing, and drying, is the accurate control and continual replenishment of fluids as they flow in contact with the emulsion surface. The development of the shape of the paraboloidal shell formed between film and the stainless steel faces to give the optimum conditions, which though an interesting problem in hydraulics and chemistry, is considered outside of the scope of the present discussion.

What has been described in the foregoing is the action of two valves, one to produce a vacuum, and the second to admit a solution. In the present equipment three other valves are used, one below and two above the plane shown in Fig. 2.

Each of these valves opens to a plumbing line similar to (8) in Fig. 2. Subsequently, in the device we are describing, valves open as follows: to developer, to fixer, to wash solution, and to air. The fluids mentioned are each in turn admitted through the center orifice and sucked out through the annular ring aperture.

Thus in action, developer, fixing bath, wash solution and air chase each other out in rapid succession. For the most rapid chemical performance, high velocity of movements and minimum amounts of each solution present in the shell are prerequisite. In this equipment less than 0.01 ml of solution is sufficient to fill the shell and this solution can be displaced or evacuated in 1 millisecond.

Third position: Upon completion of processing and drying, the film moves again to the station (10) where it enters a projection optical system. This system, which is an optical relay, has the final field lens (11) contained within the block.

The film as it enters this position has had all of the superficial liquid from the last processing solution removed. There remains, however, a small amount of absorbed moisture in the emulsion layer. When any appreciable amount of radiant energy passes through the image at this point, the absorbed moisture gradually "sweats" out of the emulsion. Some means must be provided to disperse this moisture and a simple and adequate means is provided by allowing low-pressure air heated by the projection lamp to flow over the film surface. As

indicated in the figure, this air enters the lens tube at (12) and passes around the lens (11) through a channel (13).

This completes a brief description of the principal functions of the heart of the apparatus (block B). Another necessary function of the block is the immediate pre-heating of the film area to be processed and of the solutions immediately before they are used.

The use of elevated temperatures to increase processing rates is well known and good use of this effect was made in the case of the preceding fast processing equipment. In this connection, it should be pointed out that there is a definite maximum safe temperature for both

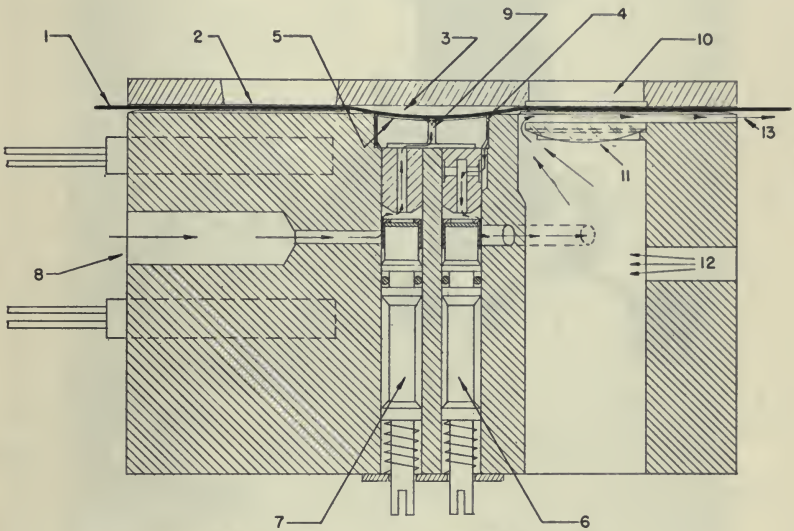

Fig. 2. Diagram of processing device.

processing solutions and film. If, because of the design of the processing equipment, some cooling of the solutions is necessary during the course of processing, the average processing temperature must perforce be less than the maximum tolerable value. Under such conditions, the processing cycle needed to reach a prescribed photographic result cannot be a minimum. To obtain this minimum time, it is obvious that temperatures should be kept at the safe maximum throughout the entire cycle.

It is to accomplish this end that into the design of block (B) have been built all the necessary heating and control units to keep both

film and solutions at the highest tolerable temperature throughout the processing cycle. The maze of plumbing, the valves, valve actuators and the thermostatically controlled heaters are, accordingly, combined in a single unit. Since the chemical activity of the solutions used must be at maximum, the materials with which these solutions come in contact must be inert, consequently the whole unit has been machined from a block of stainless steel (18–8 Mo).

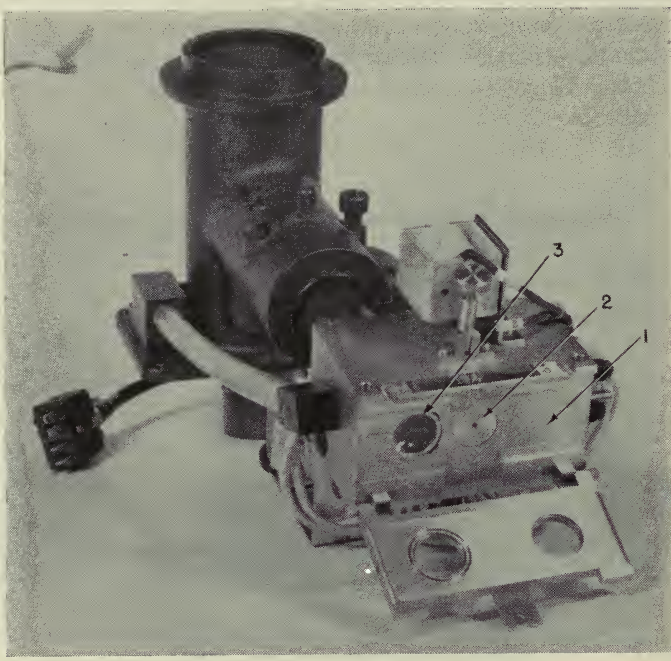

Fig. 3. Photograph of processing block with photographic station and projection lamp house.

This unit (shown in Fig. 3), though it is small enough to hold in the hand and weighs less then 3 lb, contains the following elements:

A film track and cover plate,
A 35-mm film processing machine,
A 35-mm projection-condenser optical system,
Solution heaters with thermostat control,
Solution control valves,
A film dryer.

Since a prime purpose in the development of this equipment has been the reduction of processing time compared to that of the previously described fast processing equipment, a tabular comparison of the results may be of interest. The original cycle compared to the present cycle is shown in Table I.

TABLE I

COMPARATIVE INTERVALS IN PROCESSING TIMES

(Patent 2,446,668; and present equipment Patent Applic. 114,701)

Operation	Previous equipment time, sec	Present equipment time, sec
Start developer flow	0.00	0.00
Stop developer flow	0.43	0.80
Start developer removal	3.90	
Finish developer removal	4.30	
Start fixer flow	4.50	0.80
Stop fixer flow	4.60	2.50
Start fixer removal	8.00	
Finish fixer removal	9.90	
Start wash flow	9.90	2.50
Stop wash flow	10.20	2.80
Start wash removal	10.80	
Stop wash removal	12.20	
Finish drying	12.80	3.98
Start pull-down	13.00	3.99
Finish pull-down	13.50	4.00

It should be noted that, for the same extent of development, 4.3 sec are required by previous equipment and 0.8 sec by present equipment.

For complete fixation 5.4 sec are required by the previous equipment compared to 1.7 sec for the present equipment.

With previous equipment 0.9 sec are allotted to washing; with present equipment 0.3 sec are allotted to washing.

In the previous equipment 0.6 sec are allotted to drying. In the present equipment 1.18 sec are allotted to drying. This results in a dryer film for projection with the result that the picture in the new equipment shows much less tendency to weave and warp.

In the previous equipment, 0.5 sec are required for pull-down. In the present equipment this time is reduced to 0.01 sec. The principal advantage here is concerned with the fact that during film movement data presented by the radar is lost. This loss with the present equipment is only one-fiftieth the loss with the previous equipment.

The more efficient chemical results achieved with the present equipment are due principally to two factors: (1) greater agitation of the solutions resulting from faster liquid movement, and (2) higher average solution temperature that can be maintained during the process.

The equipment uses 0.75 ml of developer, 1.2 ml of fixing solution and 0.5 ml of water per picture.

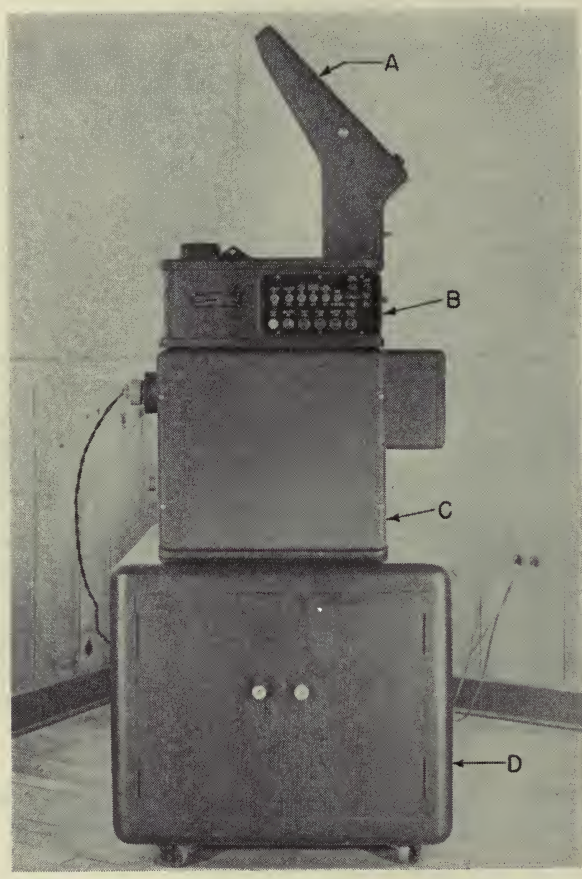

Fig. 4. General view of the camera–processor–projection unit.

Since there is nothing particularly new in the equipment aside from the parts of the system just described, description of the rest of the unit will be brief.

The whole unit, of which Fig. 4 is a photograph, consists of four sectional housings.

A is a mounting for an 8 × 12 in. front-surface mirror whose function it is to turn the projected beam horizontally. The inclination of this mirror is adjustable by fine thread screws. This adjustment is for the purpose of centering the screen image.

B is a housing for the optics, light source, processing block, film supply, and take-up.

C contains the solution supply tanks.

D contains the vacuum pump and disposal tank.

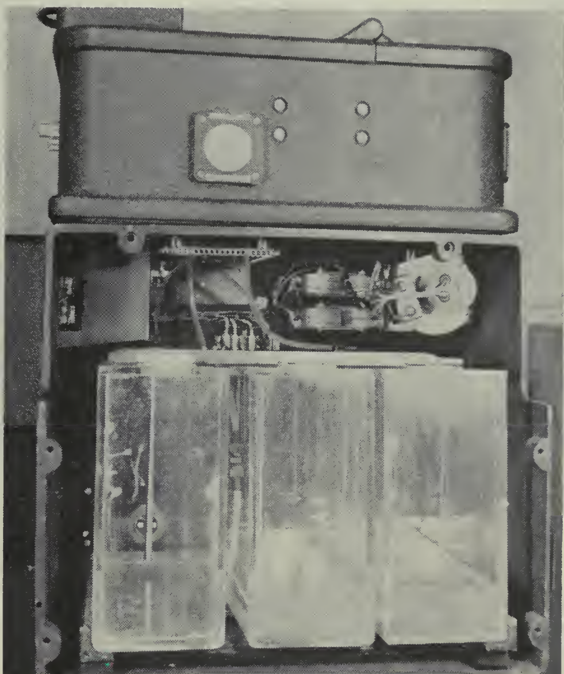

Fig. 5. Solution supply tank.

Figure 5 shows three Lucite solution supply tanks, each of 1.5 gal capacity, and each equipped with electric solution level indicators. Solutions are piped from these tanks to the processing head with ⅛ in. Saran tubing.

Figure 6 shows the interior of the lower unit with its Lucite waste tank of about 6-gal capacity. It also is equipped with a warning device to indicate its state of fullness.

Cycling Control System

Figure 7 shows the cycling control system. The right-hand cam shaft carries the necessary cams and microswitches to control all processing functions. The solution valves are solenoid-operated and

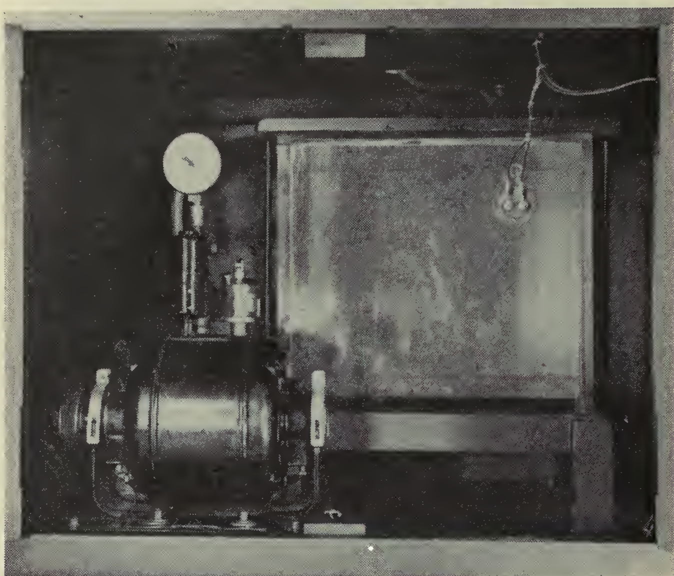

Fig. 6. Waste tank and vacuum system.

the cams are timed as indicated in the right-hand column of Table I. The left-hand cam shaft, driven by a synchronous motor, provides a timing link to the radar antenna. This cam shaft controls the film pull-down and ensures that a complete 360° sweep of the PPI tube will be photographed irrespective of the antenna speed.

Pull-Down

Figure 8 shows the pull-down actuator. A standard 35-mm motion picture intermittent was reworked to pull down five perforations. Figure 8 shows the intermittent drive mechanism. A rotary

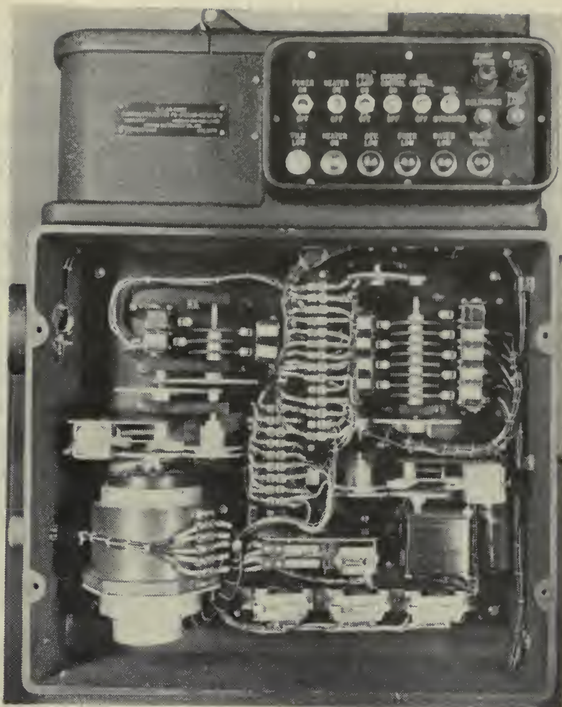

Fig. 7. Cycling control system.

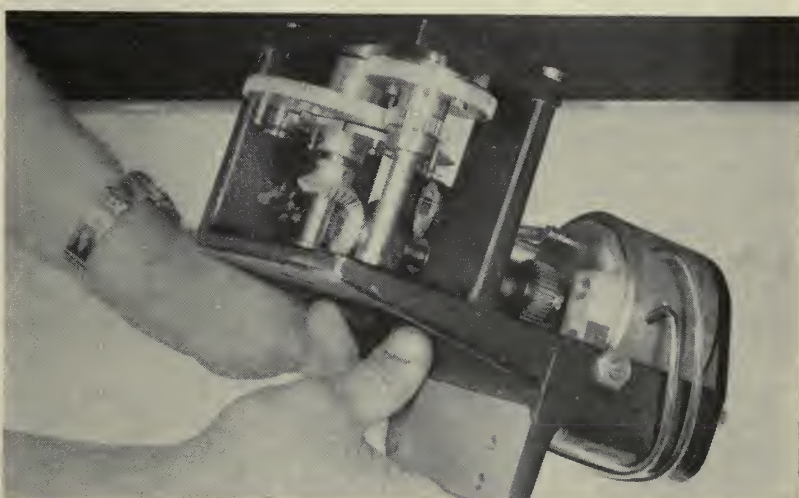

Fig. 8. Film pull-down actuator.

solenoid with a 45° stroke is geared up 8:1 to produce a 360° intermittent rotation for every stroke. Power is applied to the intermittent through a ratchet and pawl system. The pull-down is rapid (10 millisecond) and accurate. Successive pull-downs register within ± ¼ in. at a 10-ft image diameter.

Throughout the design every effort has been made to unitize the equipment so that each functional part is easily removable by unskilled field service men. Examples of complete detachable units are: the processing head, the control unit, the pull-downs assembly, the condenser system, and the objective system.

In conclusion, we wish to acknowledge the able contributions of Mr. Carl Brasser to the design of the unit that has been described. It is also a pleasure to express our appreciation for the excellent cooperation of the radar development engineers of the Watson Laboratories of the Army Air Force through whose auspices this work has been conducted.

The Trend in Drive-In Theaters

By CHARLES R. UNDERHILL, Jr.

RCA Victor Division, Camden, N.J.

Summary—A brief history pointing to the rapid postwar development of drive-in theaters based on fulfilling important needs of a huge "Forgotten Audience" is given. An outline of some of the unique design features and of the special services made available indicate why drive-in theaters offer an economical and versatile means of recreation, relaxation and general enjoyment for motorists, and a return on capital investment which is an investor's dream. Prerequisites for satisfactory projection and sound as basic requirements for successful drive-in theater construction and management, are reviewed.

The first Drive-In Theater was built near Camden, N.J., in 1933. By the end of World War II, there were only about 60 drive-in theaters, indicating that the idea had caught on slowly during those eight years before the war. It was not until after the war that the wave of open-air-see-the-movies-from-your-automobile enterprises really got under way. During the four years since VJ Day over 1000 have been constructed and many more are being planned or are under construction. As soon as unrationed gasoline again became available, the public took to the highways for the wide-open spaces. The drive-ins were doing capacity business. Prospective theater owners could not build indoor theaters at first because of government restrictions on building materials. Then followed prohibitive construction costs. It was quickly realized that drive-in theaters could be constructed of readily available materials and equipment. It was also determined that they could be built at a cost of approximately 20% of the postwar costs involved in building an indoor theater of an equivalent patron capacity, based on an average drive-in audience of approximately three persons per car.

Simultaneously, postwar projection and sound equipments were announced which had been designed and built expressly for drive-in theater use. It made obsolete most of the equipment used in drive-in theaters before the war, especially the sound equipment. The largest single factor in contributing to public acceptance of drive-in theaters is the in-car speaker, introduced by RCA in 1941 just prior to our

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entry into World War II. Experience gained previous to the war pointed the way to successful drive-in theater construction, equipment, and management. The in-car speaker removed most of the restrictions on locations where the use of centralized speaker systems at the screen would have classed them as public nuisances. For the first time, a theater patron had complete control over the sound.

To the amazement of even the drive-in theater owners, in came a type of patronage rarely seen at indoor theaters; the physically handicapped, invalids, convalescents, the aged, deaf people, expectant mothers, parents with infants and small children—whole families, dressed as they pleased in the privacy and comfort of their own domain on wheels. They are continuing to come in increasing numbers from rural, suburban, and city areas—a new clientele representing a long neglected but highly important segment of some 30,000,000 people of the "Forgotten Audience," who, according to the claims of some producers, had not been attending indoor movie theaters. These are the backbone of drive-in theater patronage, and everything is being done to retain their acceptance of the drive-in theater.

Drive-in theater patrons can do as they please within the dictates of decency in the privacy of their automobiles. They can shell and eat roasted peanuts, smoke, hold a normal conversation, regulate ventilation, and relax in wider and more comfortable seats with more leg room than possible in an indoor theater. There is no parking problem or standing in line for admission. Parents are relieved of the worries and expense associated with employing suitable baby sitters, or of the conduct of their children if left at home. Obviously no drive-in theater can afford a reputation for being lax in enforcing good conduct.

Employees like working in drive-in theaters. There is a bit of carnival or county fair atmosphere which adds to the spirit of showmanship. Even the projectionist finds a difference—instead of looking down toward the screen, he looks up, as do the theater patrons.

SPECIAL SERVICES AND FEATURES

Taking their cues from the gasoline filling stations of the leading oil companies, aggressive drive-in theater exhibitors render those extra services and courtesies which experience has proven gain public favor: windshield wiping, car towing, tire changing, a free gallon of gas for dry tanks. Many other services have been made available to the public which are customarily not found in most indoor theaters. There are diaper and other vending machines carrying personal

items, free bottle warmers for baby formulas, a nurse in attendance, call service for doctors or others subject to emergency service calls.

Thus, the drive-in theater has long since passed from the novelty category into the realm of big show business. As the number of drive-in theaters has increased, picture availability has improved, bringing in the regular movie-going public by the car-full. Returns on capital investment are an investor's dream and have been so startling as to attract new capital from sources far remote from the theater business. The maintenance costs of drive-in theaters have been estimated to run as low as 20% of those for an indoor theater. The concession business of the drive-in theater is the envy of almost any roadside stand and is estimated to account for about 25% of the gross income.

Each year, rapid strides are manifest in drive-in theaters. There is now available a highly scientific modern toll system, a modification of collection systems used at the largest bridges and tunnels, which is a substantially foolproof method of collecting and recording toll receipts, at the same time eliminating the use of tickets. There are airplane drive-ins and canoe drive-in theaters. Glamour prevails in many drive-in theaters, featuring lighted waterfalls over the rear of the screen tower, beautiful landscaping, and ultra modern concession stands with exclusive names such as "Snack-N-Vue Bar" and "Din-A-Peek Restaurant." In fact, everything is being put into drive-in theaters which experience indicates the public likes with their outdoor moving picture entertainment. A free rein has been given to the imagination in the architects' plans, each new plan vying with those of competitors for increased public acceptance of drive-in theater environment, offering an economical and versatile means of recreation, relaxation, and general personal enjoyment for each and every patron.

It thus becomes obvious that the selection of a location, the planning and the construction of a successful drive-in theater require the assistance of an experienced consultant well informed on the many complex problems which are involved. Unforeseen costs resulting from mistaken judgment on the part of inexperienced builders can force undesirable economies in the selection of the most essential elements of the over-all enterprise, namely, the projection and sound equipment. The prospective investor in a drive-in theater needs to be informed as soon as possible that the return on his investment has a much better chance of attaining his expectations if the policies of

good business practice are consistently maintained, rather than an attitude of trying to build and equip a drive-in theater as cheaply as possible.

On the assumption that the drive-in theater has been so planned and constructed that each occupant of every parked automobile can see the picture on the screen, it follows that the quality of the projected picture and reproduced sound is without exception a prime requisite for entertainment enjoyment.

Ever since the first drive-in theater was constructed, the question of the amount of light on the screen has been the main bottleneck of this type of theater. It has been not too many years since a 30-ft screen was considered a large screen for in-door theaters. Today, there are a great many drive-in theaters where screens are 60 ft wide or larger. The average patron may have the feeling that when we double the width of the screen, we should correspondingly double the amount of light available. Unfortunately, however, since we are talking about screen area, instead of doubling the amount of light we have to multiply it by four to retain the same light level over the total area of the screen.

This crying demand for more light on drive-in screens has resulted in more powerful arc lamps. In general, as the amount of light at the aperture increases, a point is finally reached beyond which it is dangerous to go because of damage to the film. Certain manufacturers have introduced heat filters which may remove approximately 40% of the heat with a 20% loss in light. Frequently, it is found that excessive costs for both carbon and power consumption can be avoided by reducing the operating amperage and eliminating the heat filter without decreasing the light on the screen. In other words, there is no point in having a high light level only up to the heat filter and then having a 20% loss in light, unless the over-all amount of light transmitted to the projector is appreciably higher than would be the case if the whole setup operated at a lower amperage without a heat filter.

One other important feature is that a heat filter may have a 20% loss in light on the day of installation, but this light loss may appreciably increase as time goes by, due to two causes: (1) the efficiency of the heat filter may decrease with age; and (2) dirt on the surfaces of the heat filter will reduce its light transmission.

Consequently, a heat filter is a unit which is continuously getting worse with age. In general, then, very much more effective operation can be obtained if a conventional heat filter with its light absorbing properties can be omitted.

There are two general classes of arc lamps currently used in drive-in theaters: (1) the reflector type, using amperages of approximately 80 to 85 amp on a 9-mm black high-intensity positive carbon; and (2) condenser type arc lamps, using amperages ranging from 130 to 180 amp.

The essential difference between the amplifier systems designed for drive-in theater use and those for indoor theater use is the higher audio power required for distributing peak signals without distortion to large numbers of in-car speakers, often totaling 1000 or more.

A typical drive-in theater amplifier is shown in Fig. 1. This amplifier has a total power output of 250 watts. It is a dual-channel system with the inputs connected in parallel, but with the output from each channel connected to one-half of the total number of in-car speakers.

At the top of the amplifier rack is the terminal strip for making external connections. Directly below is the channel selector switch and test panel. Next follow the two voltage and two 125-watt power amplifiers.

Figure 2 shows the manner in which the amplifiers can be turned down on their hinges for easy access to the circuits when servicing. The channel selector switch makes it possible to operate with both channels simultaneously as a dual channel system or, in the event of trouble in either channel, to switch the entire speaker load onto the output of the operating channel. At the same time, this switch changes the output transformer tap to match the speaker load. The disabled amplifier is automatically disconnected from the a-c power source and the output load, so that it can be repaired without interrupting the performance. Monitoring and testing facilities are also included on the selector switch panel.

The voltage amplifiers are two-stage units having high impedance inputs and transformer coupled outputs. The soundheads are connected to the inputs by means of low-capacity cables. Coupling between the voltage and power amplifiers is accomplished through a 500-ohm "H" type variable attenuator which serves as the volume control. The attenuator is connected as a dual 250-ohm variable "T" attenuator so that both channels are equally controlled.

The power amplifiers are three-stage Class "B" units utilizing four 809 type tubes in the output stage and are rated at a 125-watt output each with less than 3.5% distortion between 50 and 5000 cycles. Approximately 10 db feedback between the output and driver stages

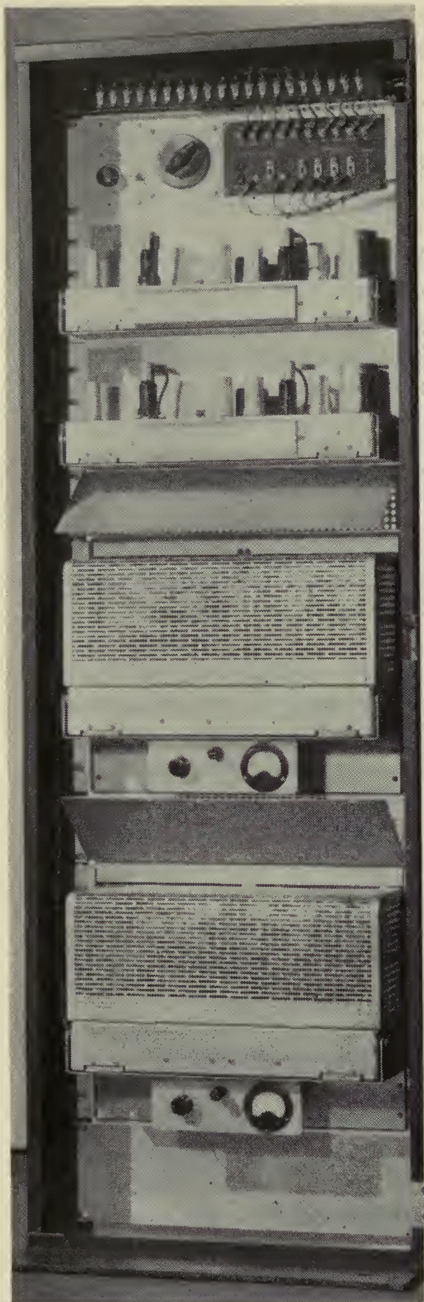

Fig. 1. Drive-in theater amplifier.

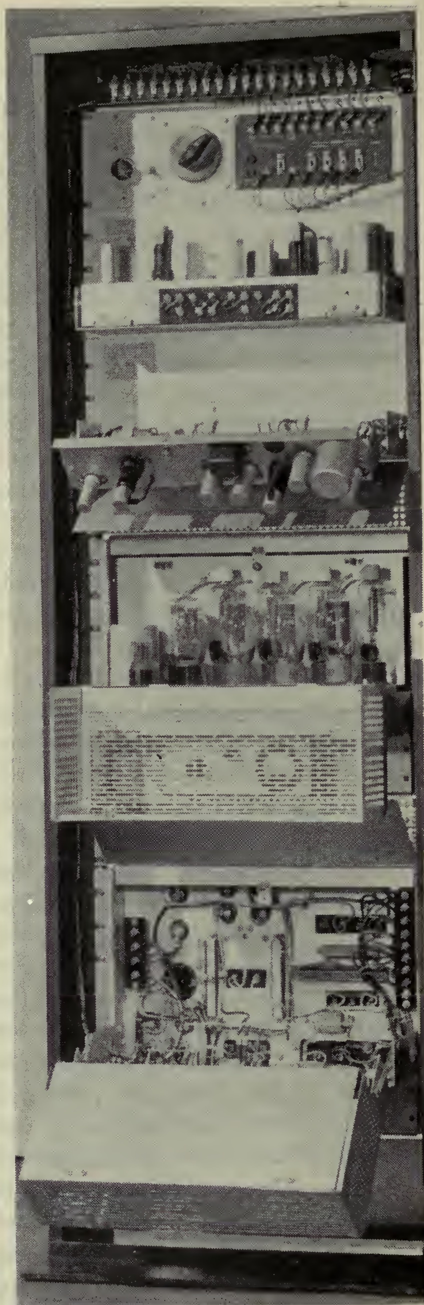

Fig. 2. Amplifiers turned down.

contributes to holding the distortion to this low value, and also serves to hold the output level substantially constant with variations in speaker load.

Figure 3 is a ramp station comprising two speakers and a junction box. The speaker housings are of die-cast aluminum, rugged enough to withstand being run over by an automobile without crushing. They are small in size and light in weight and are easily handled with one hand.

Fig. 3. Ramp station of two speakers and junction box.

The hook or neck construction was designed so the speaker can be hung on the car window, with the window almost closed, as would be necessary in rainy or cold weather.

The volume control knob is of bright red plastic and is tamper-proof.

A simple rheostat volume control is used in the voice coil circuit of the speaker.

The mechanisms used in these speakers are especially designed for drive-in speaker use. All metal parts, including the magnets, are heavily plated with cadmium. The magnets are anchored to the

frame so that they cannot shift and cause the pole piece to move off center. The voice coil and diaphragm are waterproofed and constructed to withstand all outdoor weather conditions, including floods. A drive-in theater at Endwell, N.Y., was under water for three days, submerging all of the speakers and junction boxes. When the theater was finally reopened, all but three of the speakers played perfectly.

The junction boxes are also of die-cast aluminum and have the same type of finish as the speakers.

Figure 4 shows the post and road light, and the method used to obtain a cone of light at the base of the post and project an adjustable

Fig. 4. Post and road light.

beam of light out into the driveway in the shadow area between the rows of parked cars. The junction boxes are available with or without this feature.

The miniature 28-volt, .17-amp lamp is supplied by a 32-volt power transformer located in the booth, with the voltage dropped through specified line resistors. The lamp was designed for airplane use and has a rugged shockproof filament assuring long life. This type of lighting eliminates any apprehension on the part of the automobile driver who is obliged to turn off his headlights on driving into the theater. There can be no fear of hitting an unseen person or object, because each roadway light serves continuously to usher the

driver safely toward a parking space. The pattern of elongated lighted areas in the roadway follows the curved contour of each ramp. The over-all effect, including the lighted areas at the base of each post, gives the drive-in theater a beautiful appearance, with ample lighting within the parking area at a minimum of cost. In a 1000-car theater,

Fig. 5. Junction box with lamp for concession attendant.

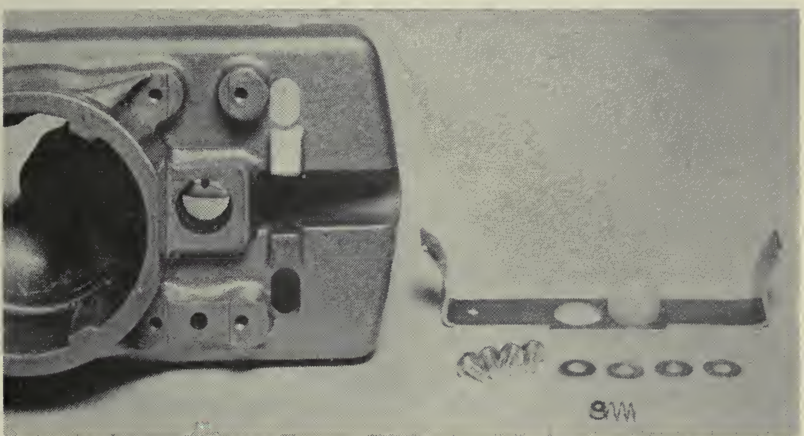

Fig. 6. Mechanical device for concession signaling.

for instance, there are 1000 beams of light from 500 tiny lamps with a total power consumption of only approximately 2 kw.

The transformer is completely moisture proof. It has a high impedance primary winding which permits connecting many in parallel across the amplifier output.

For concession service, an additional miniature lamp is installed in the junction box which is readily seen by the concession attendant as a red glow from a lens located in the junction box cover, Fig. 5. The patron controls the light by means of a toggle switch installed in the face of the speaker housing.

Three types of speaker cables take care of basic requirements. There is the low cost straight cord, and the deluxe Koiled Kord. A theft resisting cable includes a hardened stranded steel cord which is anchored at both ends. It also includes three conductors and is standard for use with electrical concession lights.

Another type of concession signaling device is entirely mechanical, Fig. 6. It is simply a stainless steel slide attached to the under part of the junction box base, and so constructed that the patron can push or pull it and cause a red lens to intercept the down light beam of the post light, causing it to change from white to red. The lens is plainly visible to the concession attendant.

Unsolved Problems and the Future

The problems of daylight projection involved in endeavoring to obtain longer daily operating hours, and of in-car heating so as to expand the operating seasons, are apparently being given much thought. They both need a practical solution applicable to every section of the country. Fog is a serious problem in some areas, occasionally becoming heavy enough to cause refunding of admissions.

Regardless of such remaining problems, there is every indication that the public needs and wants more drive-in theaters, if strategically located, wisely constructed, and properly equipped.

The trend is toward drive-in theaters having smaller car capacities which can adequately serve rural or suburban communities. Many have already outgrown their car capacities. The solution has been simple and economical in those theaters owning sufficient land. It has been necessary only to add and equip one or more ramps.

Indications are that an undetermined number of well-established drive-in theaters which have been in operation for several years have made plans for improvements and for replacing their old equipment.

All of these activities are conclusive proof that the drive-in theater business is here to stay. Exhibitors were literally pushed into it as an aftermath of World War II. In the opinion of the author, only a World War III can be its Nemesis.

A Sturdy, High-Quality 16-Mm Projector

By G. T. LORANCE

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And F. B. DIBBLE and H. J. REED

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Summary—A 16-mm sound motion picture projection system according to U.S. Navy Bureau of Ships Specification CS–P–41A must meet high-quality standards for picture and sound reproduction, while retaining the necessary durability for Navy use. It must provide high light output with good light distribution, long film life, low flutter, low distortion, and good frequency response. A projector designed for this purpose uses a sprocket type intermittent and unit component construction for ease of maintenance. The paper describes the projector mechanisms and amplifier circuits, and states performance results.

The 16-mm sound motion picture projection system to be described has been developed in part under a contract with the United States Navy Bureau of Ships. The specification which has been used as a guide throughout this development is in many respects an extension of Specifications American Standard Z52.1 and Joint Army-Navy P–49. In effect, it calls for a system which has performance approaching 35-mm standards, as well as the necessary sturdiness to withstand severe Navy use. Initial review of conventional 16-mm components indicated that one or the other of these requirements would have to be sacrificed to some extent if conventional 16-mm techniques were followed throughout. The most promising approach seemed to be to incorporate the desirable features of 35-mm techniques into a 16-mm projector. In keeping with this idea, new components were developed where necessary and were adapted to existing components to establish the projector design. The amplifier and loudspeaker units were developed with similar objectives in mind.

The three basic units, projector, amplifier and loudspeaker, may be operated as a single-projector, single-amplifier system (Fig. 1), or may be expanded into any combination of two projectors and two

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amplifiers. For change-over operation, a junction box is required to interconnect the two projectors. Each unit is housed in a separate carrying case which has space for accessories and operating spares. The cases are made of a newly developed sandwich laminate of cellular-cellulose-acetate bonded between thin aluminum sheets. Panels of this material are lightweight, but are extremely rigid. Covers are gasketed to seal against moisture and dust.

The projector mechanism is shock-mounted at four points in the carrying case. Sealed ball bearings lubricated with high temperature

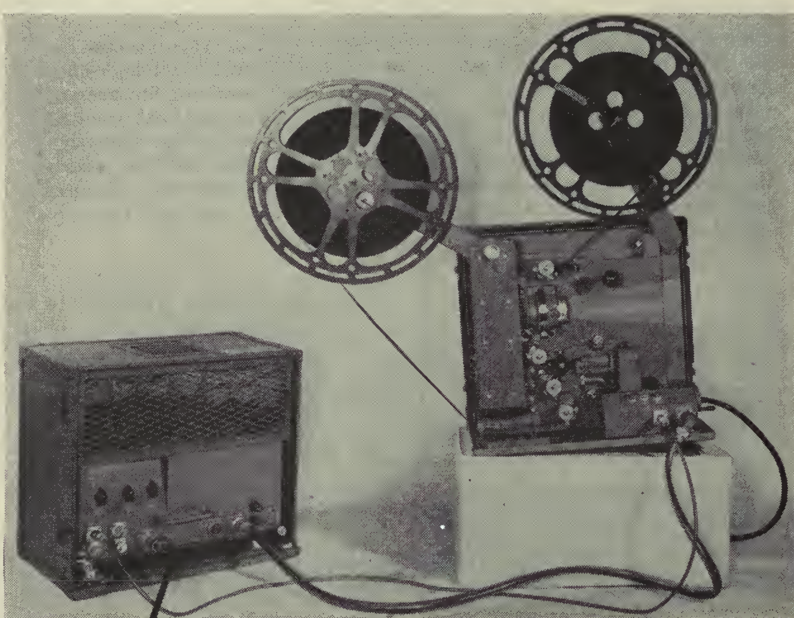

Fig. 1. Projector and amplifier.

grease are used on all shafts except those in the intermittent mechanism, where sleeve bearings are used. To minimize the effect of corrosion, the materials employed are protected aluminum alloys, copper alloys, corrosion-resistant steel, or fiber.

PROJECTOR

The projector (Figs. 2 and 3) operates from 115-volt 60-cycle alternating current. Film is transported at the sound speed only, namely,

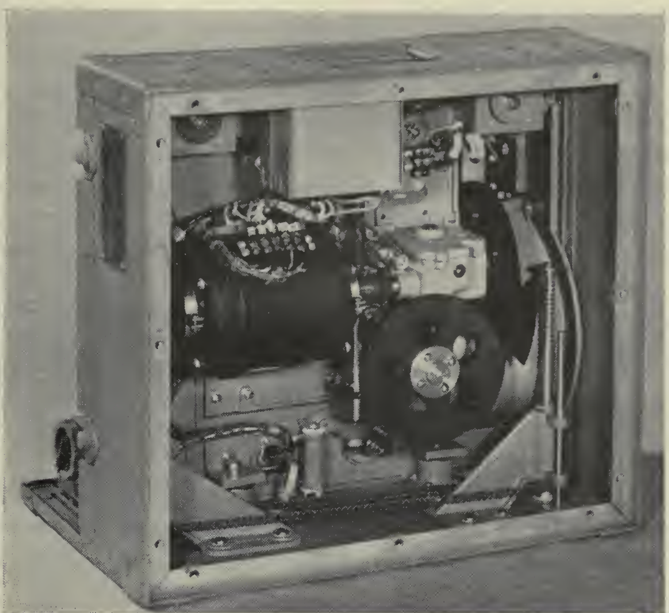

Fig. 2. Projector, mechanism side, cover removed.

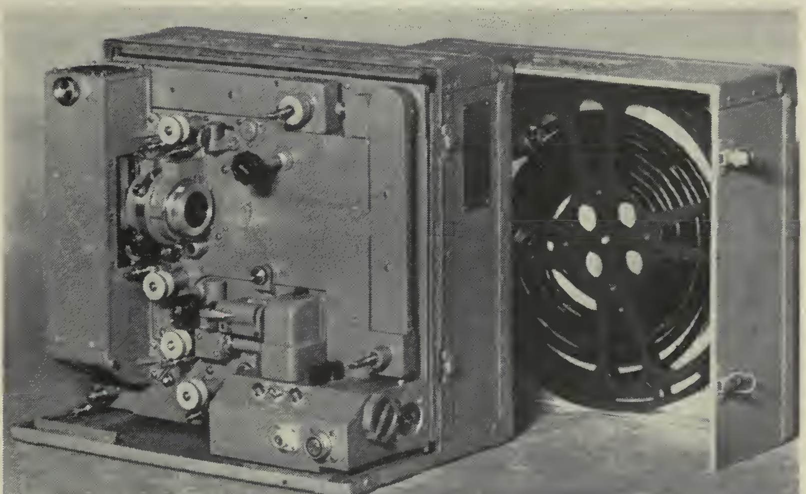

Fig. 3. Projector, operating side.

24 frames/sec. Reel arms, tilt mechanism, and electrical outlets are wholly enclosed within the carrying case, and a 2000-ft reel is carried in the cover of the case. The reel arms are an integral part of the projector, and are both positioned above it in operation. For ease in assembly and service, the projector uses a vertical main frame to which components and subassemblies are fastened. The components which make up the projector are discussed below.

Drive Motor

An 1800-rpm, synchronous type drive motor is used in preference to a governor-controlled unit. Although the synchronous motor is the larger and heavier of the two, its quieter operation, more constant speed, and the fact that it requires no brushes are decisive points in its favor.

The centrifugal starting switch in the motor is interconnected with the projector controls so that the projection lamp cannot be energized unless the motor is running.

Intermittent Mechanism

The projector uses a sprocket type intermittent mechanism which provides a four-tooth continuous film control. This type of intermittent provides a favorable stress distribution at the sprocket holes, and has a corresponding advantage in regard to film life. Film life tests[1] have shown that several thousand passages may be made without damage to the sprocket perforations.

The mechanism is housed in an oil-filled gear box receiving an input drive from the synchronous motor and providing output drives for the shutter, intermittent sprocket, and the vertical shaft. The shutter shaft is driven at 1440 rpm through a single mesh of spiral gears.

The principal parts of the mechanism are shown in Fig. 4. The 12-tooth intermittent sprocket (1) is indexed by a 12-tooth star wheel (2) and a cam (3) which has a 50° operating section on the shutter shaft. The star wheel teeth are held in contact with the dwell surface of the cam by a preloaded, spirally coiled, flat spring (4). The center of the spring is fixed to the star wheel shaft and the outside of the spring is fastened to a spur gear. The spur gear unwinds the outside of the spring at a uniform rate while the center is being wound up at the same average rate by the intermittent action. Using spring loading in this manner not only simplifies the cam construction but

also provides automatic wear take-up during the life of the mechanism. Since but one surface is required for tooth registration, machining of a tooth-confining cam surface and the need for close tooth-thickness tolerances are eliminated.

Framing is accomplished by moving the shutter shaft axially. This movement shifts the registration surface of the cam, rotating the intermittent sprocket. The projection aperture thus remains stationary on the screen during framing, and the picture moves within this aperture.

Sealing the gear box against oil leakage has been effected by the use of Johns-Manville synthetic rubber shaft seals which are pressed into the housing and flexibly grip the shafts.

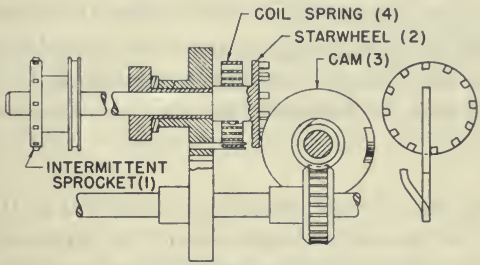

Fig. 4. Schematic of intermittent mechanism.

The shafting arrangement of the intermittent mechanism has permitted the use of a large disk type shutter to achieve a relatively high light efficiency. With an $8\frac{1}{4}$-in. diameter shutter, located $\frac{3}{8}$ in. from the film plane, a light efficiency of 73% has been attained.

A V-belt pulley assembled as part of the shutter drives a $3\frac{3}{16}$-in. diameter blower-wheel at 2450 rpm for ventilating the lamp house. The relatively slow operating speed minimizes blower noise. However, the blower wheel is large enough to realize a free-air discharge rating of 140 cfm at this speed.

Gate and Film Trap

The gate and film trap have been designed to register the film on the emulsion surface for standard 16-mm emulsion position, and to guide the film from the sound track side. Guiding the film in this manner conforms to ASA specifications. Chandler, Lyman, and Martin[2] have ably discussed the film guiding problem with respect to

lateral film shrinkage. When the film is guided at the perforated edge, a rail between sound track and picture area which will not encroach on the sound track becomes impracticably small. This results from the fact that the sound track, being opposite the guided edge, will be shifted nearly the full amount of the shrinkage. In guiding the film from the sound track side, the shift between the picture and sound due to shrinkage is a smaller proportion of the total, and therefore a reasonably large rail can be provided. Registration on the emulsion side of the film eliminates any effect of in-and-out-of focus which might arise from variation in film base thickness.

For threading, a lever at the top of the film trap casting retracts the spring-loaded, film side guides and, at the same time, lowers the intermittent sprocket shoe. The film trap body and pressure shoe form a funnel-like entrance which defines the film plane. The film, in entering, depresses the pressure shoe, providing the necessary gate opening. The film trap casting is removable for cleaning purposes, at which time the pressure shoe also becomes accessible.

Lamp House

The complete lamp house assembly is mounted at the back of the main frame. The projection lamp and optical elements are supported on the lamp house door, and are thermally insulated from it. Either a 750-watt or a 1000-watt incandescent lamp may be used.

The projection lamp is a newly developed General Electric type which burns base up. It has a medium ring, double contact base. The mechanical mounting ring on the base is independent of the electrical contacts, and is large enough to permit very accurate positioning. Filament size, construction, and bulb size are consistent with current practices. However, since the lamp operates with the filament in the downward position, the cooling air strikes the hottest portion of the lamp first, which should result in more effective cooling and correspondingly longer lamp life. Also, any blackening of the interior wall due to evaporating tungsten occurs far enough above the optical axis so that there is very little loss of light during the life of the lamp.

When the lamp house door is open, the lamp is easily lifted out for replacement; it is held in position by the spring-loaded electrical contacts only when the door is closed. Opening the door actuates a safety switch which de-energizes the contacts in the top of the lamp house.

The projection optics consist of a Bausch & Lomb 22-mm single aspheric condenser lens with a 39½-mm spherical reflector, positioned behind the projection lamp. The combination of an accurately positioned projection lamp and these optics produces the high screen illumination and good light distribution shown in Table I.

Table I

System Performance Characteristics

Light Output (shutter running),	750-watt lamp:	320 lumens
	1000-watt lamp:	430 lumens
Uniformity of Illumination (% of center),	average corner:	92%
	lowest corner:	85%
Picture Unsteadiness (% of picture width),	vertical:	0.2%
	horizontal:	0.1%
Flutter (measured on RCA Meter No. MI-9763-B),	average:	±0.25%
	maximum:	±0.35%
Noise of Projector Mechanism: 63 db above 10^{-16} watts/sq cm		
Power Output: 20 watts with less than 2% distortion from 100–4000 c/sec		
Frequency Response from Film: 3 db below midband level at 80 and 5000 c/sec		
Electrical Noise Level (controls set at normal): 55 db below 20 watts		

Lens Mount

The lens mount accommodates objectives having the dimensions shown in JAN–P–49. A one-piece focusing sleeve, cut longitudinally, clamps and locates the lens barrel. The design utilizes the elastic properties of the sleeve to grip the lens barrel securely, while permitting ready release by a cam crank in the longitudinal cut. The end of the sleeve forms an accurate register surface for the shoulder on the lens barrel, so that the lens can be returned to exact position after removal for cleaning. A double thread on the outside of the sleeve provides fine focusing.

The projector is equipped with a Bausch & Lomb 2-in., *f*/1.6 Supercinephor "16" lens which resolves better than 90 lines/mm over the whole screen. Lenses with focal lengths between two and four inches can be accommodated.

Take-up

The take-up device utilizes the weight of the film on the reel to provide variation in driving torque so that reasonable film tension may be maintained under all conditions. With proper adjustment, a 5-oz tension in the film may be obtained with an empty reel, and

this tension decreases to approximately 2 oz when 2000 ft of film have been taken up.

Rewinding is accomplished without interchanging reels. The rewind drive, engaged by a mechanical switch near the feed sprocket, handles 2000 ft of film in 3½ min. A slip clutch allows the full reel to coast to a stop without damage to the drive when the projector is shut off.

Sound Head

The sound scanning mechanism is an integral unit assembled through vibration isolation mounts to the main frame. The prefocused exciter lamp is operated from a radio-frequency power supply in the amplifier. The Bausch & Lomb scanning lens tube is similar to those used in 35-mm projectors, except that the adjusted-jaw mechanical slit has been reduced in size so that the width of the slit image is approximately 0.0005 in. The scanning beam thus obtained is independent of the size of the lamp filament. From the theoretical consideration of the scanning losses[3] the zero-output frequency for an 0.0005-in. scanning beam is 14,400 c/sec (cycles per second); at 7,200 c/sec, the output is down only 4 db.

A double convex lens mirror focuses the light beam onto the cathode of a blue-sensitive gas photocell. For film having emulsion in the nonstandard position, a plane parallel piece of slide cover glass approximately 0.011-in. thick is inserted in the light beam to shift the focus from one surface of the film to the other. In this way the fineness of the slit image is retained for film with nonstandard emulsion position. Provision has been made for focusing the optic tube as well as adjusting it in azimuth and in lateral position.

The mechanical filter[4] which transports the film through the sound head consists of a film-driven eddy current drag sprocket, a flywheel on the scanning drum shaft, and a flexibly driven sound pulling sprocket. The inertia of the flywheel on the scanning drum shaft and the compliance of the spring in the flexibly driven sound sprocket determine the low cutoff frequency of the filter. The eddy current drag sprocket damps any oscillation at the natural frequency of the filter, and also provides frictional torque for rotating the scanning drum so that a pad roller with its attendant difficulties is not required. The coil in the flexibly driven sound sprocket is preset in relation to the torque imposed by the eddy current drag so that a film loop is formed on starting the projector. The film loop thus formed

isolates the intermittent from the sound head and at the same time establishes synchronization between picture and sound. A second film loop between sound and holdback sprockets isolates the sound head from the effect of the take-up.

Amplifier

The amplifier has been designed to meet Navy mechanical and electrical specifications, and consequently differs considerably from amplifiers used in current commercial projectors. It supplies a power output of 20 watts to a 4-ohm load, with distortion considerably below the required maxima of 2% between 100 and 2,000 c/sec, and 4% between 2,000 and 4,000 c/sec. The normal frequency response of the amplifier is 3 db below the midband output level at 80 and 8,000 c/sec. Separate treble and bass tone controls provide adequate range to compensate for most acoustic and film deficiencies. The amplifier gain is sufficient to develop a 20-watt output from 400-c/sec level test film, with a reserve gain of 20 db when minimum specification limit tubes are used. Connections are provided for microphone input and for a monitor speaker.

Circuit

The circuit consists essentially of an input feedback loop, one stage of amplification containing the volume and tone control circuits, and an output feedback loop.

A pentode and a triode stage are included in the input feedback loop where about 25 db of over-all negative current feedback are used. The feedback reduces the effective input impedance of the amplifier to the extent that a capacity as high as 200 micromicrofarads in the photocell cable causes no appreciable change in the amplifier output at 10,000 c/sec. A 15-ft length of RG71/U signal cable could thus be accommodated. Cable microphonics, hum, and distortion are also attenuated.

A 40-db attenuator having 2-db steps is used as a volume control. From this control, the signal is amplified in a single triode stage which drives the tone control network. The range of boost and attenuation afforded by the separate low and high frequency controls is shown in Fig. 5.

The output feedback loop includes three stages: a triode amplifier, a triode phase inverter, and a power stage using push-pull 6L6GA tubes in class AB_1 operation. Feedback voltage developed across the

secondary of the output transformer is coupled to the cathode of the triode amplifier stage, giving 10 db of over-all feedback.

Exciter Lamp Supply

An oscillator type power supply for the 6.5-volt, 2.75-amp exciter lamp is built into the amplifier chassis. The oscillator uses a single 6L6GA tube which operates at a frequency of 30 kilocycles per second, and has an efficiency of about 50%. With this type of power supply, the exciter lamp filament is not subject to cyclic temperature variations within the audio range, as it would be if it were operated from a 60-cycle source.

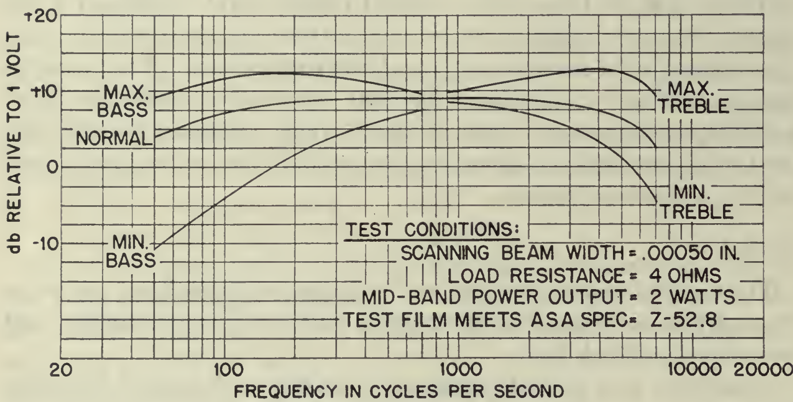

Fig. 5. Frequency response.

Construction

The components have been selected to give as reliable operation as possible under extremes of shock, vibration, temperature and humidity. All paper condensers and transformers are hermetically sealed. The carbon tone control potentiometers are of the molded element type. Insulated carbon resistors and vitreous enameled power resistors are used throughout, and are operated at less than 50% of their power ratings. Three hermetically sealed plug-in electrolytic condensers are required as cathode by-pass units, but the amplifier will function at slightly reduced gain with any of these removed. All other condensers are either mica or oil-filled paper units, operated at less than 75% of their voltage ratings.

The aluminum alloy chassis is given a high degree of rigidity by partitions and angle reinforcing members which also provide shielding and mounting supports for terminal strips. The chassis is secured in the carrying case by a shock absorbing aircraft type rack, and may be removed for servicing by loosening two thumb-nuts. Spare tubes, electrolytic condensers and lamps are housed in the amplifier carrying case.

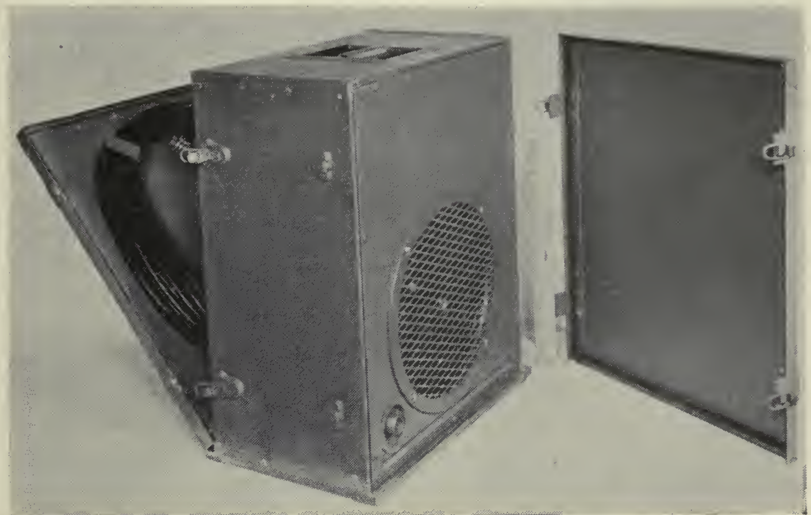

Fig. 6. Loudspeaker.

Loudspeaker

The Western Electric Model 754B loudspeaker, used with this equipment, is a 12-in. diameter unit with a 4-ohm nominal impedance. It has a high power handling capacity, and is constructed to withstand heavy shock and vibration. It is the only known commercially available reproducer having both the required efficiency and a phenolic impregnated cloth cone. This loudspeaker is operated with the back of the carrying case (Fig. 6) closed, the enclosed volume being approximately that recommended by the manufacturer.

Acknowledgment

A development of this nature represents necessarily the combined efforts of many individuals. The authors gratefully acknowledge the collaboration of Mr. E. G. Mercier and Mr. A. F. Hayek. Thanks and appreciation are also due those who have assisted in the various stages of the work.

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Animar Series of Photographic Lenses

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Summary—A new series of highly corrected lenses, with focal lengths ranging from 12.7 mm to 100 mm, has been designed for 8-mm and 16-mm cinematography. The speed of some lenses in this series is as high as *f*/1.5. Some general problems of optical design and of evaluation of lens performance are discussed. Strict criteria are used for appraising the quality of these lenses, which will be introduced on the market under the name of *Animar*.

About three and a half years ago the late Dr. W. B. Rayton introduced[1] to the Hollywood convention of this Society a series of new *f*/2.3 Baltar lenses of short focal lengths. These lenses were primarily intended for new professional 16-mm cameras that were reaching the final design stages and were about to be introduced on the market at that time. Considering the preference of some camera manufacturers for using their own focusing mounts, and because of uncertainties as to whether all camera manufacturers would eventually adhere to the same mounting dimensions, the Baltar lenses were offered in plain barrels, and the fitting into focusing mounts for any particular camera was left to the camera manufacturers. This has limited the use of Baltars to just a few types of cameras whose manufacturers have been willing to undertake the task of mounting.

In the meanwhile the extensive engineering efforts of many individuals and organizations have resulted in a number not only of 16-mm professional, but also of 16-mm semi-professional and 16-mm and 8-mm amateur cameras. Most of these 16-mm cameras are capable of accommodating lenses having the mounting thread of 1.000 in. × 32 and the registration distance of 0.690 in., and practically all 8-mm cameras accommodate lenses of 0.625 in. × 32 thread and the registration distance of 0.484 in. Thus a wide interchangeability of lenses now is possible and an extensive market is available for lenses of these standard mounting dimensions.

Characteristic of this market is the demand for high-quality products at a reasonable price. Due to the great improvements made

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during and after the war in engineering and manufacturing, camera manufacturers have been capable of meeting the quality requirements to such an extent that in many cases the difference between a "professional" and a "nonprofessional" camera can be attributed not to some performance deficiency of the latter but only to its lacking a number of special features which are considered essential for efficient motion picture production on the Hollywood level. Disregarding some exceptions, it seems fair to state that the basic limitations of the present-day 16-mm and 8-mm motion picture photography lie not in the mechanical shortcomings of cameras but in the inherent restrictions imposed by the laws of optical image formation (problems of depth of field and difficulties of exact focusing with lenses of short focal lengths) and by the materials used for photographic recordings (granularity of emulsion and warpage of film). Some of these optical factors will be evaluated in another paper planned for a future convention.

TABLE I

ANIMAR SERIES OF MOTION PICTURE LENSES

For 8-mm Cameras			*For 16-mm Cameras*		
Focal length, mm	$f/$ number	Diagonal coverage,* degrees	Focal length, mm	$f/$ number	Diagonal coverage,* degrees
12.7	2.8	24.3	15	3.5	43.8
14	1.9	22.1	25	1.5	27.1
15	1.5	20.6	25	2.7	27.1
25	2.7	12.5	26	1.9	26.1
37.5	3.5	8.3	50	3.5	13.7
			75†	3.5	9.2
			100†	3.5	6.9

All these lenses have the standard mounting threads and the registration distances mentioned in the beginning of this paper.

The lenses for 16-mm cameras may be mounted on 8-mm cameras by means of special adapters.

* Based on the projector frame.

† Named Tele-Animars.

The mechanical excellence of many postwar cameras and the general education of the public to the appreciation of better motion picture photography necessarily impose the requirement of high quality also on the lenses for these cameras. This requirement is eminently met by the Baltar series. However, the requirement of a price which "the general public can afford" and the occasional need for lenses faster than $f/2.3$ Baltars had to be met by another series

of lenses, which are being introduced on the market under the name of Animar. A list of these lenses is given in Table I.

GENERAL NOTES ON OPTICAL DESIGN AND ON PERFORMANCE EVALUATION

The purpose of designing this series was to produce lenses that would be economical from the point of view of the manufacturer and the purchaser. Hence an effort was made to utilize a minimum number of components without sacrificing the basic requirement of high-quality performance. Extensive research and development work was needed for meeting this condition. Finally it was found possible to use not more than four elements for practically the whole series, with the exception of the $f/1.5$ lenses in which design six elements were necessary in order to meet the desired quality of performance.

In this connection and for a better appraisal of the results, it seems worth while to discuss some misconceptions with regard to design and performance evaluation of optical systems. These misconceptions are: that a high quality of optical performance cannot be achieved unless many elements are utilized in the lens construction; that there are some new developments in lens design which make obsolete all previously used formulas; that a formula originally developed for a certain angular coverage can always be improved if the required angular coverage is reduced; and that resolution tests can serve for absolute evaluating of lens quality. All these statements have grains of scientific truth, but they cannot be accepted without severe reservations.

There is no general rule for determining the minimum number of elements necessary for producing a high-quality optical system. For example, in astronomical telescopes, which require almost perfection in performance, only two elements may be sufficient because of the extremely narrow angular coverage at a low speed. More than two elements are usually required for covering an extended field at a speed higher than about $f/8$. It was a truly great contribution to the field of photographic optics when in 1893 H. D. Taylor developed a triplet design (frequently known as the "Cooke Lens" because at that time he was with Cooke and Sons of York, England), and clearly demonstrated that three elements may be sufficient for obtaining a speed as high as $f/4$ and a coverage up to at least 25° from the axis. The suitability of triplets has been later extended to speeds approaching $f/2.5$ Disregarding some special designs such as the Kellner[2] and

Schmidt systems employing reflective components and correcting plates, it seems that at least four elements are needed for obtaining an extended coverage at speeds in the neighborhood of $f/2.0$, or even higher if the coverage is limited to a few degrees from the axis. One of the principles of fast four-element designs was discovered by J. Petzval as early as 1840, and ever since it has been employed for producing very satisfactory photographic and projection lenses. The Petzval constructions frequently fail, however, when the requirement is to cover a field greater than about six degrees from the axis at a high speed; then more elements are usually necessary for a satisfactory image quality in the periphery of the field.

It is fortunate that mostly moderate angular coverages are involved in motion picture photography. Thus with "standard lenses" (focal length of ½ in. for 8-mm cameras, and of 1 in. for 16-mm cameras) the diagonal field actually utilized for projection is less than 27° (that is less than 13.5° from the axis), and it may be just a few degrees for a "telephoto" lens. Therefore, three- and four-element designs may be particularly suitable in this application.

In regard to recent or future new developments in lens design, it should be sufficient to state that a thorough knowledge of fundamental principles and limitations of optical systems had been acquired by the end of the last century, and that practically all basic constructions were already in existence in the early part of this century. The progress since that time has not revealed itself in any fundamental discoveries, but in a broader exploration and a deeper understanding of theoretical relationships pertaining to optical design, and in their practical application to further development of some promising rudimentary forms. By extreme modifications and extensive compounding of these forms, some designers have succeeded in exploiting the inherent, but previously overlooked or not explored, possibilities, and in developing novel constructions of almost spectacular characteristics, thus practically reaching the limits of the possible in optical design. The evolution of the Gaussian type objectives, mentioned later in the text, is particularly illustrative of the creative thinking in lens design. One of the major factors in this progress has been the increased choice of optical glasses. There is, however, no hope that this choice may be extended indefinitely, and no hope that some new revolutionary principles of design will be discovered. It seems that the time is approaching when major explorations in optical design should come to an end with nothing left to do but the tedious task

of cleaning up details, which is, according to a recent paper by George Gamow,[3] a fate looming for physics in general. Actually the "cleaning up of details" has been, for some time, the major activity of optical designers. This activity has resulted in many excellent systems providing either speeds or angular coverages or both far above those that could be anticipated with the basic forms. The successful development of these systems, however, only emphasizes the fact that unless some radically simplified solutions of design problems are discovered, no great advances should be anticipated either from further modifications of the now available forms or from increasing their complexity by further compounding.[4] As the matter stands now, it is highly illusory to entertain hopes that the desired simplified solutions are forthcoming.

It is superfluous to state that, if the best possible results are to be achieved, an optical system should always be designed with due regard to the intended application. This does not mean, however, that a lens designed for a given coverage can be readily made better for a less extended coverage, or that some other system can be chosen for a superior performance within the reduced field. The fact is that each case should be treated in accordance with its merits, and that quite often no substantial gains can be made by redesigning a system for a narrower coverage. This is particularly true when the original system was designed for a relatively small coverage, and its oblique aberrations were reduced to a negligible minimum. Then the performance of the system within a still smaller coverage will be determined primarily by its residual spherical aberration. If the residual in the original design was reduced to a minimum desired by the designer, it would be purposeless for him to attempt a redesign of this system for a smaller coverage.

In the course of this work the goal was to produce a series of lenses whose aberrations would be most favorably balanced for the field of the 8-mm motion picture frame, and to produce another series specifically for the 16-mm frame. Still all the lenses intended for 16-mm cameras will perform equally well on 8-mm cameras. If, for example, a question should be raised whether or not the design of the 100 mm $f/3.5$ Tele-Animar could be advantageously modified for 8-mm coverage, the answer would be an emphatic "no," because the residual aberrations of this form were reduced to insignificant amounts even for a larger coverage, that is for the entire area of the 16-mm frame. As a matter of fact the correction of this formula is so satis-

factory that it can be used for covering the 35-mm frame without substantial sacrifices of the image quality in the extended field, excepting, perhaps, its very margin.

The problem of determining the performance of a lens has often been reduced to a recording of "its photographic resolution" on the assumption that a resolution record can reveal the intrinsic quality of the lens. Testing for resolution is of much value in evaluation of lens performance; nevertheless, the method has definite limitations which have been recently surveyed by a number of investigators including one of the authors.[5,6] The basic fact is that a photographically recorded resolution pattern generally reveals neither the performance of the lens itself nor that of the emulsion itself, but that of the lens-emulsion combination.

If the lens is practically free from aberrations, its intrinsic resolution potentialities are indicated by its Airy disk (discussed in the papers referred to above) whose diameter is a function of the lens f/number and of the wavelength of light used in the image formation. The photographic resolution obtainable with a nearly perfect lens is essentially limited by the resolving power of the emulsion used, unless the emulsion resolving power is higher than the "Airy resolution" of the lens; then the lens becomes the limiting factor.[7]

The situation becomes much more complicated in the presence of aberrations. Then the lens itself becomes the primary limiting factor which always tends to keep the attainable photographic resolution of a lens-emulsion combination under the maximum resolution of the emulsion. Therefore, if a lens within a certain area of its coverage is capable, for example, of recording a resolved pattern of 100 lines/mm on some emulsion (whose resolving power will have to be somewhat higher), no conclusion can be drawn that the "resolving power of the lens" will not be the limiting factor in photography on emulsions of resolving power lower than 100 lines/mm. Indeed it may happen under some conditions that in photography with the same lens on a low-resolution emulsion the resolution will be significantly below the rated resolution of the emulsion.

Due to the extreme complexity of the situation and the lack of standardization of resolution tests, data on the resolution recorded with a lens may be highly misleading if they are not accompanied by an identification of the target and the emulsion used in the tests, and if they do not reveal the lens performance within the entire intended area of coverage. Even when these qualifications are met, the data

may be of little value in absence of comparative data for similar lenses of other makes. Such data are generally not available.

Attempts have been made to determine the inherent performance characteristics of image-forming systems either by an analysis of the energy distribution within aberrated image patterns (D. G. Hawkins and E. H. Linfoot,[8] M. Herzberger,[9] A. Maréchal,[10] and others) or by the ingenious recording of response-resolution curves of the systems (O. Schade[11]). These investigations are definitely a move in the proper direction. Their application to routine rating of photographic lenses will have to wait, however, until the methods and the instrumentation involved become more widely accepted among optical industrial laboratories, and until an extended experimental material is accumulated.

Irrespective of the significance that may be attached to these investigations or to any resolution data, the residual aberrations of a lens are the primary indicators of the degree of perfection attained in its design. The situation here is also very complex as, in order to obtain a satisfactory performance, it is necessary not only to reduce all the aberrations to an acceptable minimum but also to obtain a most favorable balance of all the residuals within the entire field of coverage. Because of this complexity and of the unavoidable compromises, it is impossible to rate a state of correction of a lens by some numerical coefficient that would express the relative standing of a design among other designs. Nevertheless, the rather extended published material on the correction of various formulas provides a relatively good basis for a qualitative comparison, and, in the case of a high degree of correction, the comparison may be based on the tolerances derived from the Rayleigh quarter-wavelength criterion of perfection. The basic forms of these tolerances may be found in the well-known book by Conrady.[12] These tolerances will be used for an appraisal of the representative Animar formulas.

It should be understood that, when used in connection with photographic optics, the Rayleigh tolerances seem so severe that optical designers generally do not hesitate to accept residual aberrations several times greater than would be acceptable on the basis of the Rayleigh criterion. The problem of meeting these tolerances becomes increasingly difficult for lenses of longer focal lengths because the linear aberrations in lenses derived from one basic formula are directly proportional to the focal length, while the Rayleigh limits are independent of the focal length. Considering these facts, Conrady,

a man of unquestionable authority in optical design, found sufficient justifications for establishing less strict tolerances for coma, astigmatism, and curvature of field. In the appraisal of the Animar series these *practical* tolerances will be referred to, as well as the strict tolerances based on the original Rayleigh criterion.

DESIGN AND PERFORMANCE CHARACTERISTICS OF ANIMARS

The Animar series, in its present stage of development, consists of lenses utilizing three, four, and six elements in their construction.

Since the first triplet was derived by H. D. Taylor, many successful efforts have been made to improve the formula and extend its usefulness. There are now a multitude of triplet formulas recorded in general and patent optical literature, and many triplet constructions have been widely utilized by manufacturers of photographic and projection lenses. A number of triplet formulas have been continually

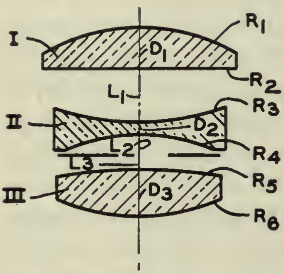

Fig. 1. Basic form of triplet Animars, U.S. Patent No. 2,453,260.

$f/2.7$, Focal Length 100 mm

Lens I	R_1 = 40.94	D_1 = 8.74	N_D = 1.6170	
	R_2 = ∞	L_1 = 11.05	ν = 55.0	
II	R_3 = 55.65	D_2 = 2.78	N_D = 1.6490	
	R_4 = 39.75	L_2 = 7.63	ν = 33.8	
		L_3 = 7.63		
III	R_5 = 107.56	D_3 = 9.54	N_D = 1.6170	
	R_6 = 43.33		ν = 55.0	

used by Bausch & Lomb. Some of them could be readily and satisfactorily employed for this particular application. Still, it was considered desirable to explore further possibilities of a better design, and extensive studies were made of the existing triplet constructions before the basic formula was finally derived for the triplet Animars.[13] This basic formula is represented in Fig. 1. Its modifications were used in the construction of the following lenses: 12.7 mm $f/2.8$, 25 mm $f/2.7$, 37.5 mm $f/3.5$, and 50 mm $f/3.5$.

The excellent state of correction of these constructions may be illustrated by comparing the residual aberrations of the 12.7 mm $f/2.8$ Animar with the Rayleigh–Conrady tolerances (Table II). The following reservations should be noted with regard to this comparison. In deriving the formulas for tolerances, Conrady subjected the Rayleigh criterion to certain interpretations, and he made certain assumptions which are not necessarily realized in every design and under

the actual conditions of focusing a lens. Thus the tolerance for marginal spherical was derived on the assumption that this aberration is preponderantly primary in a lens under consideration; this, however, practically never occurs in well-corrected lenses in the range of speeds represented by the Animar series. The tolerance for zonal spherical was based on the assumption that the marginal spherical is reduced to zero, which is not a generally preferred state of correction. The derivation of the tolerance for astigmatism and curvature of field involved the supposition that there is no vignetting and that the lens is focused on the image plane midway between the axial and the marginal focus. Since all these conditions are hardly ever satisfied simultaneously, the Rayleigh–Conrady tolerances may be rigor-

TABLE II

CORRECTION OF THE 12.7 MM $f/2.8$ ANIMAR

Aberrations	Rayleigh–Conrady Tolerances		Residual Aberrations*
Marginal spherical		0.08 mm	+0.01 mm
Zonal spherical		0.11 mm	−0.09 mm
OSC′:	strict	0.06%	
	practical	0.25%	0.01%
Comatic patch:	strict	0.005 mm	
	practical†	0.025 mm	0.008 mm
Curvature:	strict	0.01 mm	
	practical†	0.14 mm	T −0.05 mm
			S −0.09 mm

* All the aberrations are for D spectral line.
The oblique aberrations are for 12.5° field angle.
† For extremely sharp definition.

ously applied only in some special cases of extremely well-corrected systems. The other extreme is represented by the systems with residual aberrations many times greater than the Rayleigh–Conrady tolerances. Then, no useful information can be obtained from referring to these tolerances. When, however, a system is so well corrected that its residual aberrations approach the tolerance values, a juxtaposition of the residuals and the tolerances should serve well at least for illustrating the merits of the design, if not for its quantitative rating.

The 15 mm $f/3.5$ Animar for the 16-mm frame is the Tessar type. Its correction is almost as perfect as that achieved in the 12.7 Animar although the angular coverage in this case is nearly two times greater. Due to the lower speed, the spherical aberration is even better corrected than in the 12.7 Animar, the zone being less than one third of

the Rayleigh–Conrady tolerance for $f/3.5$ lenses. The coma is well corrected within the entire field, and in the very margin of the field it is still near the Conrady practical tolerance. Both tangential and sagittal curvatures are well within his tolerance.

It was particularly difficult in this case to meet the coma tolerance because it was undesirable to resort to the usual expedient of reducing the diameter of the peripheral image-forming pencil and sacrificing the corner illumination. It was believed that uniformity of illumination should be considered a very important requirement particularly since the advent of color photography. Hence, an attempt was made to provide a relatively wide-angle lens with a corner-to-center ratio of illumination as high as could be obtained without accepting undue compromises with the image quality in the margin of the field. This effort resulted in a formula with the illumination ratio of 40% at the field angle of 22°. The authors believe this is a very satisfactory result, considering the fact that for ordinary $f/3.5$ Tessar constructions of short focal lengths the ratio is usually below 30%, and that among the many $f/3.5$ and faster lenses (of focal lengths from ½ to 5 in.), either in our sample collection or reported in literature, only one $f/3.5$ lens[14] with the relative illumination as high as 50% at 22° was found. It should be noted that the problem of illumination distribution usually becomes more difficult for faster lenses. Still, even for $f/1.9$ and $f/1.5$ lenses in the Animar series a relative illumination greater than 40% was secured at the margin of the usable field. The ratio for the slower Animars of longer focal lengths is, of course, considerably higher. It increases with focal length, and approaches 100% for the 100-mm Tele-Animar.

Four elements are used in the $f/1.9$ Animars. The sequence of their powers is plus–minus–minus–plus, which arrangement has been successfully utilized in a number of other designs (type L-c of the Kingslake classification[15]). The limitation imposed by the small number of elements was a serious obstacle in attempts to obtain a high degree of correction for these formulas. Nevertheless, a design was finally produced whose oblique aberrations, referred to an average plane of focus, do not significantly exceed the practical Conrady tolerances for $f/1.9$ lenses. In order to eliminate the disturbing effects of a focus shift when the lens is stopped down (this is a quite common phenomenon in lenses for general photographic purposes), the marginal spherical aberration was left over-corrected, while the zonal spherical was reduced to less than two times the strict Rayleigh–Conrady limit.

In the authors' judgment, the over-all correction of these lenses is equal to or better than that of other similar designs, and their photographic performance was found highly satisfactory in Bausch & Lomb laboratories and in independent tests.

Four-element constructions have been frequently used for $f/1.5$ lenses, and their deficiencies have not been too severe at least in amateur motion picture photography. It was thought, however, that at the present level of the art, and particularly in professional applications, a considerably higher degree of correction is needed than seems to be obtainable with four-element constructions of $f/1.5$ speed. For this reason six elements were used in the $f/1.5$ Animars. The construction is of the Gaussian type, whose origin and evolution are well described in a paper by A. Murray.[16] The excellent potentialities of this type of construction have been exploited in a number of successful designs, as may be represented by the well-known Baltars, Biotars, and some types of Ektars.

TABLE III

CORRECTION OF 15 MM $f/1.5$ ANIMAR

Aberrations	Rayleigh–Conrady Tolerances		Residual Aberrations*
Marginal spherical		0.02 mm	−0.03 mm
Zonal spherical		0.03 mm	−0.06 mm
OSC′:	strict	0.03%	
	practical	0.25%	0.14%
Comatic patch:	strict	0.003 mm	
	practical†	0.025 mm	0.047 mm
Curvature:	strict	0.003 mm	
	practical†	0.08 mm	T −0.02 mm
			S −0.04 mm

* All the aberrations are for D spectral line.
The oblique aberrations are for 11.0° field angle.
† For extremely sharp definition.

The formula of the $f/1.5$ Animars is closely related to that of the $f/1.6$ Super Cinephor projection lenses for 16-mm film, which were introduced by A. Neumer to the preceding SMPE convention.[17] Major design work was, however, required for obtaining a satisfactory state of photographic correction at the $f/1.5$ speed. The correction of the basic formula is illustrated in Table III.

The formula utilized in the design of the 75 mm and 100 mm $f/3.5$ Tele-Animars may be classified as a triplet construction with the front element split into two elements, the second of which is a menis-

cus. A prototype of this construction may be traced back to a formula produced in 1925 by L. Bertele.[18] This prototype was later subjected by a number of designers to extensive modifications some of which involved the introduction of additional elements and their compounding. From these modifications evolved the Sonnar lenses whose excellent characteristics are generally recognized. It seems, however, that the highly favorable possibilities offered by the basic four-element construction have been neglected for some time, particularly in this country, although the construction has been commercially utilized by the British. Only recently has a revival of interest been revealed by some designers.[19]

The triplet construction with the split front element is highly favorable to a satisfactory correction of spherical aberration at fast speeds, for an excellent correction of coma, and apparently for a

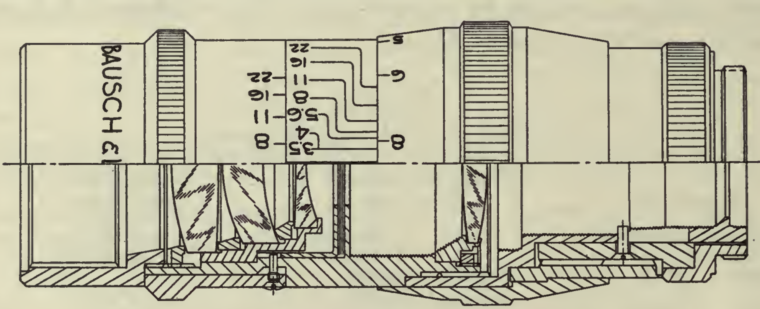

Fig. 2. 100-mm Tele-Animar $f/3.5$ in focusing mount.

better correction of astigmatism and of curvature of field than is obtainable with other fast constructions utilizing only four elements (the Petzval and related types). However, the curvature of field still remains the basic limitation, so that the coverage can hardly be more than about 15° half-angle if strict criteria are used. This coverage is approximately represented by the minimum focal length of 10 mm for 8-mm frame, of 25 mm for 16-mm frame, and of 50 mm for 35-mm frame.

The excellent characteristics and the apparent limitations of the four-element construction were thoroughly analyzed in the course of the Tele-Animar design. On the basis of these studies, the conclusion was reached that, as compared with a simple triplet, the split triplet construction offers definite advantages particularly for covering the 16-mm frame with lenses of focal lengths longer than 50 mm. Conse-

quently, a four-element formula of the type just described was designed for the 75 mm and 100 mm Tele-Animars, illustrated in Fig. 2. The speed of these lenses was limited to $f/3.5$, although it easily could be made higher. The reason for this conservatism was that the almost ideal correction of the formula at $f/3.5$ made the authors reluctant to accept even minor compromises just to gain in speed designation, especially considering the fact that a high speed is rarely of much importance in "telephoto" use. The speed of the 50 mm and 37.5 mm Animars was kept at $f/3.5$ for the same reason. The correction of the Tele-Animar formula is summarized in Table IV.

TABLE IV

CORRECTION OF 100 MM $f/3.5$ TELE-ANIMAR

Aberrations	Rayleigh–Conrady Tolerances		Residual Aberrations*	
Marginal spherical		0.12 mm		+0.07 mm
Zonal spherical		0.17 mm		−0.07 mm
OSC′:	strict	0.04%		
	practical	0.25%		−0.10%
Comatic patch:	strict	0.006 mm		
	practical†	0.025 mm		0.013 mm
Curvature:	strict	0.01 mm		
	practical†	0.18 mm	T	+0.03 mm
			S	−0.03 mm

* All the aberrations are for D spectral line.
The oblique aberrations are for 3.5° field angle.
† For extremely sharp definition.

In the preceding discussions pertaining to the correction of the Animar series, nothing was said about its color correction. This is because a satisfactory color correction is regarded as an obvious prerequisite of any modern lens intended for motion picture photography. While this requirement usually is met without serious difficulties, no magic procedures can be derived for obtaining a "superior" color correction of fast lenses covering a substantial field, because a limitation is basically established by the now available selection of optical glasses. Therefore, a cursory remark should suffice: that the secondary spectrum for every lens in this series was reduced to the generally anticipated and accepted limits, and that the oblique color was not permitted to exceed a few microns even with the lenses of longer focal lengths.

Finally, it should be noted that, in appraising the performance of a lens, the user naturally cannot disregard its behavior at other stops

than the maximum, unless his intentions are to deal only with some special situations requiring all the available speed of the lens. In this connection, observations are frequently made to the effect that, because certain compromises are unavoidable in fast lenses of any design, a fast lens stopped down should be necessarily somewhat inferior to a lens specially designed for use at that lower stop. There are no inherent factors that would make such a situation generally valid. Indeed, with a favorable balance of its residual aberrations, a lens should improve when it is stopped down, and at the smaller stops it may be as good or even better than any other specially designed slower lens. This situation actually prevails in the Animar series. As any one of these lenses is stopped down, its residual aberrations do rapidly diminish, and at a stop in the neighborhood of $f/5.6$ practically all of them are brought substantially under the corresponding strict Rayleigh–Conrady tolerances. This advantageous characteristic of the Animars follows almost self-evidently from the fact (illustrated in the preceding tables) that their residual aberrations even at the maximum apertures are either under or comfortably near the respective tolerances, and it may be further substantiated by the following numerical data. The Rayleigh–Conrady tolerance for the marginal spherical at $f/5.6$ is 0.31 mm; the tabulated data indicate that this tolerance is much larger than the residual spherical even of the wide-open Animars; when they are stopped down to $f/5.6$, the residual becomes entirely negligible in comparison with the corresponding strict tolerance. The Rayleigh–Conrady strict tolerance for coma at $f/5.6$ is 0.01 mm; for the 12.7 mm $f/2.8$ formula at $f/5.6$ the trigonometrically computed comatic patch is 0.005 mm (less than the Airy disk, whose diameter at $f/5.6$ is 0.008 mm); the patch for 15 mm $f/1.5$ at $f/5.6$ is 0.014 mm and for 100 mm $f/3.5$ at $f/5.6$ it is 0.009 mm. The strict tolerance for curvature of field at $f/5.6$ is 0.04 mm and the practical (for extremely sharp definition) is 0.28 mm; the actual residual curvatures of the Animars (see the tables) are within these limits even with the lenses wide open.

The authors do not claim that some special procedures were used for obtaining this favorable state of affairs. The gratifying results should be attributed to perseverance and luck, which are indispensable, though not omnipotent, ingredients of any successful optical design.

Acknowledgments

Accomplishments in any large organization seldom can be attributed to only one or two individuals. Credit is gratefully given: to Misses L. M. Hudson, B. N. Marble, and L. B. Frey for their extensive contributions in the optical development of the Animar formulas; to Mr. C. DeGrave, who was primarily responsible for the mechanical design; and to Mrs. M. H. Tarplee for her patient measurements of the experimental samples.

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DISCUSSION

MR. HERBERT LOWEN: Can you tell us whether the field curvatures were computed along the principal ray or for the full fan?

DR. PESTRECOV: As usual, correction of curvature as shown in the slides was computed along the principal ray; but, of course, the residual coma contributes to the effective curvature. We try to over-correct the fan to compensate for any under-corrected residual curvature along the principal ray or vice versa. If we have over-correction of the principal ray, we try to under-correct the fan at that particular angle to compensate for that, with the aim of providing as flat a field as possible with the wide open beam at the particular point in the film.

MR. LOWEN: And the tangential difference was for the corner?

DR. PESTRECOV: Yes.

MR. LOWEN: And what was the maximum astigmatic difference?

DR. PESTRECOV: In most of these lenses, because the angles are small, the corner really represents the maximum difference.

Color Cinematography In the Mines

By M. CHARLES LINKO

Cinematographer, Chicago, Ill.

Summary—**Problems involved in 16-mm color cinematography in the mines are discussed. Details of power supply, distribution, and voltage control are explained. Various photographic techniques necessary to the obtaining of exposure, color quality, and modeling under adverse conditions are illustrated.**

Color cinematography in the mines is a challenge to the imagination as well as to the physical endurance of those who undertake it. Of ten assorted mines visited by the author, over a traveled distance of 11,000 miles, a salt mine lent itself most favorably to photographic requirements. Nevertheless, it, too, offered those basic obstacles peculiar to other similar ventures underground.

Entering a mine with two tons of photographic equipment was a laborious and tedious job. Skip hoists were small, limiting a load to only a few items. To lower eight 5,000-watt Senior spotlights with standards required four trips in many instances. In addition there were six 2,000-watt Junior spotlights, four Broadside Doubles[1] floodlights, hundreds of feet of cable, transformers, and the usual array of carrying cases.

After the equipment was lowered to the working level of the mine on the skip hoist it was loaded on a train of cars for the trip toward the scene of operations, usually a mile or more from the shaft. Arriving at a transfer point it was then reloaded to a number of shuttle cars and drawn to the "face" of actual mining operations. Thus, many hours were spent moving about within the mines.

The Salt Mine

In the salt mine the "roof" rose from ten to twenty feet permitting lighting from parallels constructed of available workbenches and boxes. The uneven floor of a room was leveled where each lamp was to be placed and the casters were set in channels cut with a pick.

Since the source of power was usually within a hundred feet of the

Presented: October 11, 1949, at the SMPE Convention in Hollywood.

shooting area at the mine face, the anticipated voltage drop through loss in cables, in addition to the load drawn by the mining machinery, suggested the use of the Color Photographic Type 115-volt, 3350 K (degrees Kelvin) lamps with Kodachrome Commercial Film. Because this emulsion is balanced for 3200 K it required only further reducing the voltage, and consequently the color temperature, in order to satisfy its color balance characteristics.

In this mine, supplied with 460-volt, three-phase alternating current, it was necessary to use two 15-kva, 4-to-1, double primary and secondary type transformers connected open delta. This permitted connection of two 100-ft three-wire cables with two six-hole plugging boxes to the secondary terminals of each transformer. These were placed in close proximity to the lamps. Fortunately, telephone communication with the power plant and excellent co-operation from the mine officials made it possible to obtain the desired voltage for any setup, thereby solving the major problem in this mine.

Color temperature control was accomplished by referring to the lamp manufacturer's color temperature factor curve for the proper voltage required to operate the lamps which indicates a color temperature change of approximately 10 K/volt. Accordingly, the 102 volts necessary to yield 3219 K was adhered to as closely as circumstances permitted. A rise to 108 volts or 3276 K was tolerated. On close setups numerous lamps were allowed to remain burning outside the area being photographed in order to prevent a voltage rise beyond the desired level. The voltage readings were made at the lamp base. The consequent loss of light intensity resulting from this manner of voltage control was overcome by the use of the Maurer Professional Camera with its 235° shutter opening. The key light was set at 500 ft-c at $f/2.8$ as compared to 900 ft-c recommended by the film manufacturer.[2] Working with a lower level obviated the necessity for intense spotting of the light beams, or the alternative of moving in with the lamps, either of which would have limited many long shots. The effect was that of even over-all illumination without crowding the narrow rooms and passages with a battery of floodlights.

Kicker lights or crosslights were added to enhance the scenes but only in rare instances was backlighting possible. To obtain the illusion of depth, a slightly more intense beam, properly directed and diffused with black scrim, was played on the background from the side, thus preserving the rugged texture with slight shadow detail. It was not uncommon to conceal a lamp in the set behind the very machine

being photographed, often lowering the lighting unit into a pit excavated for the purpose.

A common difficulty was that of lighting a long, narrow tunnel where the far wall was to be seen in the picture, yet much of the action was to take place within the passage. This action often included a huge piece of mining machinery passing by and taking up all of the passageway but a few feet on either side. In order to obtain sufficient light for exposure, niches were made in the ribs and the lamps concealed within them; light beams were reflected off the roof and the distant ribs; a lamp was tied to the back of the moving machine; front lights were crisscrossed and flooded, or gradually diffused and reduced in intensity with black scrim as the machine approached the camera—every artifice was put to use. The extreme range of light level required for the scene before the action had taken place, as opposed to that required during the enactment, taxed all available facilities. Nothing short of remote-controlled shutters on the lamps would have served to better the condition.

Moisture combined with salt particles in the air to form hydrochloric acid, requiring that the camera and accessories be dubbed with lanolin to ward off corrosion. Lenses were constantly being dusted. The emulsion chosen required no color correction filter, thereby eliminating the troublesome annoyance of caring for dusty or fogged filter surfaces.

At the end of each shooting day all equipment had to be broken down and moved to a passage known to be idle overnight because work crews progressively blasted in each section. Frequently it was necessary to load it on cars, have it hauled to a safe passageway, only to haul it back to the same place the following morning.

Upon completion of shooting in this mine, it was noted that the action of the salt had extensively attacked the metal standards, plugging boxes, and the like, necessitating a thorough cleansing before leaving the location.

The footage made in the salt mine, aided by the soft reflective nature of the mineral, was of "high key" value. The slight blue-gray tint in the rock was characteristically reproduced in favor of the blue tending toward the green in the shadows. The gray values seldom occurred as a true mixture of black and white. The orange-lacquered mining equipment added to the beauty of the settings and was shown to excellent advantage in the wide corridors.

THE POTASH MINE

In the potash mines the rooms, ranging from eight to twenty feet in width, were less spacious than in the salt mines and the roofs, about ten feet high, were lower. The mineral was salmon colored, with strata of salt producing what might be a child's conception of "Candy-land." Like salt, potash, being almost opalescent, does not reflect harshly.

Fig. 1. The more spacious salmon-colored potash mine, where illumination difficulties arose from surges caused by the operation of heavy mining machinery such as the shuttle-car, a portion of which can be seen in the right background (*Photo by* Tom Toia).

The opening scenes were to be filmed in rooms adjacent to those being mined. The heavy loading machines drained the power supply, causing a fluctuation in the illumination. The only recourse was to light the set with this wavering illumination, instruct the personnel in the action desired, and when all was in readiness for the camera to roll, to signal the operator in the adjoining room to stop his machine. A cursory survey of the lighting was made before the take, and in this

manner the shooting progressed. The mining machine being photographed was equally offensive from the power usage standpoint, however, and only in the final cutting does the illumination remain constant in effect. The initial dimming was of necessity tolerated because the cost of running a separate line into the mine was prohibitive. Resting on the surface was a 20-kva generator used for lighting the 5,000-watt Seniors when used as boosters on exterior lighting, but which was of no value in this predicament because it could not be transported close enough to the scene of action.

Even more distressing was a bad "take" because the area became partially "mined out" in the process of the shooting and to maintain continuity the fragmentary ore had to be shoveled back into place for the retake. It may be added that a gunshot would pass unheard among the thunderous sounds of a mine in operation. Conversation, for the most part, was carried on by one's newly developed sign language.

A specific type of cutting machine was encountered in a potash mine where the rooms were extremely narrow, scarcely wide enough to permit passage on either side of the mechanical monster. There was but one direction in which to shoot and that was toward the mine face. Since the cutter's bar also worked its way forward, there was no space left for lamp placement. Closer observation of the area revealed that advancing drilling crews had left some holes in the ribs just below the roof. These served to accept some quickly improvised dowels and wire hooks from which 5,000-watt Seniors were suspended. The light beams were directed at the face allowing some light to spill over on the ribs. Two Seniors placed further back and to one side were diffused with black scrim to an intensity of 300 ft-c and directed at the workmen in the room. The camera was mounted on two boards elevated on sawhorses just a few inches above the incoming machine. The forced perspective of the 17-mm lens produced a striking elongated mine passage view as the cutting machine emerged from beneath the camera. Thus, a hopelessly restricted area was instrumental in providing an effective coverage which might have been otherwise slighted.

It was becoming increasingly appparent that lenses of the shorter focal lengths were the order of the day. A 20-mm lens was needed to supplement the rather extreme 17-mm wide angle that had been adequate in the more spacious mine. Such a lens, on order for many months, had been delivered to the distributor in the East. The cam-

era was flown to the distributor while exterior scenes were made with a Filmo.

The color obtained in the potash mines was indeed faithful to the original. The emulsion used favored those subtle tints within the warm region of the spectrum. Shadows were void of the green veiling that prevailed in the salt mine footage.

The Iron Mine

The intense humidity of the iron mines, located 300 ft below sea-level, and the ever-present staining of red iron oxide dust caused much discomfort and grief. The moist particles became imbedded in the crackle finish of the camera parts, necessitating a daily scrubbing with soap and water, all other solvents having failed. Personnel appeared to be wearing a deep shade of panchromatic make-up which luckily was photographically of material aid to their dark skins.

The dimensions of the rooms were much like those of the first potash mines. Lamp placement was more difficult here because the ore was less thoroughly pulverized. Huge piles of the heavy muck were scaled and leveled before the lamps could be set up.

Of greater consequence was the inadequate power supply. The mean average output was approximately 98 volts. Surges from various motors in use caused a drop of from 10 to 15 volts which was made doubly bad by the low reflection coefficient of the dull red surroundings. The scenes were lit in accordance with the intensity required allowing the light to go warm on the premise that the predominant color would serve as a camouflage.

Ninety-eight volts, or 3169 K, represented a departure of lesser concern at this time, for the new low voltage level drastically reduced the light intensity as well.

In order to obtain the 500 ft-c required for the flesh tones, the light beams from two Seniors placed in tandem were overlapped. Backgrounds were first evenly flooded, then the projections and recesses were crosslighted to accentuate the differences in the various planes. Takes were made until one was obtained where the power remained fairly constant, the ponderous ore being replaced after each take. The gray of the steaming atmosphere was increased by the exhaust from the air-powered drills and upon first inspection appeared to be a photographic impossibility; however, the use of a minimum of crosslights, essential to impart a feeling of depth, eliminated the fog. The effects of the lower voltage were indiscernible in the print. The moist

red rock is reproduced in vivid tones of monochrome and, strangely enough, some of the deeper shadows are veiled with a transparent film of blue.

THE ZINC MINE

The zinc mines presented the same conditions encountered in the iron mines but with one addition: water. Water rushed in torrents along the tracks; it formed puddles throughout the mine; it dripped off the roof and made a sea of mud of the working areas except for the very face of operations. The roof was so low here that one had to walk with his head tilted sidewise; then suddenly the clearance rose to a height of 75 ft.

The power supply dropped to an all-time low, the highest reading observed being 96 volts. Since this mine was supplied with 250-volt direct current, the power was tapped from the nearest trolley line. One lead, fitted with a fusable miner's nips (a rod shaped in the form of a question mark with an insulated handle at its base) was hung on the trolley line, the other being clamped to the rail. The Seniors were connected in series of two units each, making a set of four series units, or eight lamps, parallel across the line and the whole was controlled by a master switch.

Since the rock being mined was largely limestone with thin serrated strata of yellow and silver zinc, the dull gray surroundings required a great deal of light. "Effect lighting" was resorted to in the long shots resulting in a more realistic representation perhaps, but one that departed somewhat from the style conventionally used in industrial filming. Nevertheless, many takes were made before the power remained sufficiently constant throughout any single operation.

Some of the workings were photographed at night when only a small portion of the mine was functioning. Then there was an overabundance of power. The use of the variable mine car resistor at full capacity, with three Seniors burning off the set for voltage control, provided 3240 K.

The control of color temperature by voltage regulation was preferred to the use of color compensating filters because no method was available at the time for accurately evaluating filters in terms of degrees Kelvin. The feasibility of constant use of color compensating filters in the mines is questionable but, as an adjunct to partial voltage reduction, no doubt the aid of the proper filter was direly needed. The results in this mine attested to this fact because the cool gray surroundings reproduced with a steel-blue cast.

THE LIMESTONE MINE

The natural ventilation in a limestone mine with its entrance at ground level permitted driving the truck and generator to the very face of the workings. Thus, after 10,000 miles of travel, the generator finally was put to use within the mine proper. Without this ideal generator location, shooting would have been impossible because the

Fig. 2. The main haulage-way in the limestone mine, where the natural ventilation permitted the use of a generator driven by an internal combustion engine; note the Seniors in the center middle distance placed on the rocky ledge to the left of the string of cars (*Photo by* Beryl Hawkins).

power available from the mine equipment was little above that required to operate the mining machinery. The generator supplied power for six of the Seniors, the mine circuit taking the other two and some of the smaller units. With virtually complete control of illumination, shooting day and night, the crew finished in less than half the time consumed in other mines. The results here were consistent with the more favorable conditions.

THE COAL MINE

The three coal mines visited were supplied with direct current where in all cases it was necessary to reduce the voltage. With all lamps burning and the resistor in the circuit, in one instance a length of iron pipe tied into the line served to lower the output.

Some of the Color Photographic globes were replaced with the 3200 K Motion Picture Type and their beams were blended. The 2,000-watt Junior spotlamps were so used to impart a warm tone to the black mineral.

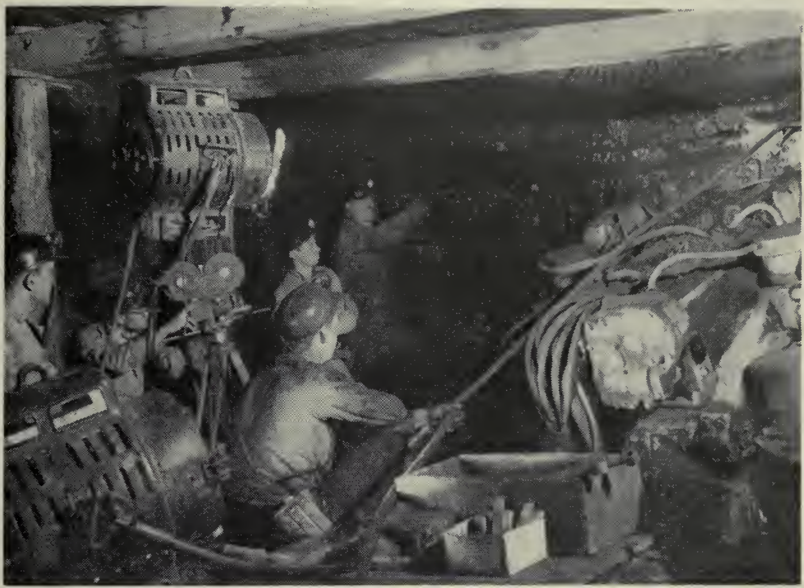


Fig. 3. Shooting a scene of a cutting machine at the "face" of operations. Photo shows nearly the full width of a typical room in a coal mine where the heat of the lamps dried the surfaces, causing slabs of coal to drop all about, and where the dust obliterated every scene, often necessitating leaving the rooms until the atmosphere cooled and cleared (*Photo by* Beryl Hawkins).

The major difficulty in a coal mine is that of balancing the flesh tones with the dark surroundings. When the coal surfaces appeared without the beneficial, reflective layer of rock dust, 1,600 ft-c were required on the coal surface to accomplish this balance. Moreover, the surface was deliberately marred to create a texture of minute colorful reflections.

The timber supports used in the coal mines add to the lighting difficulties because they, too, are light in color, although they served well to conceal many lighting units.

Another difficulty was that of keeping the participants within predetermined boundaries. The miners would inadvertently walk into a "hot" beam of light intended for the illumination of a mound of coal. The problems experienced in other mines were amplified here because of the absence of bright surfaces from which to reflect the light rays. More dust prevails in a coal mine. In addition, all mine surfaces, save the floor, are covered with rock dust and this fine abrasive is in constant circulation. The intense heat of the lamps sometimes dried the roof, causing slabs to drop all about. This was more frequent in a low mine where the roof was a mere forty inches above the floor. At such a time it was necessary to leave the area to allow the surfaces to cool. Moving about on one's haunches for a number of hours added physical pain to the other difficulties.

The long scale gradation of Kodachrome Commercial Film was undoubtedly most appreciated upon viewing the footage made in the coal mines. The full brightness range was covered with magnificent detail in both extremes. There is a mild coolness about this footage much of which was photographed at 3240 K. Black dust particles in the air and indeed the cold nature of the surroundings were contributing factors. Backlighting on a stream of coal imparted a rust-red hue to the mineral, otherwise it photographed as a true black with varicolored catch lights.

Conclusion

Obviously the major problem in mine cinematography is the somewhat indefinite power availability. Except in some naturally ventilated mines, generators, driven by internal combustion engines are prohibited. A voltage stabilizer would have been an asset, for very little photography may be done at night when the power is in lesser demand. Nevertheless, cinematography in the mines is fascinating for there is much color there. True, it does present seemingly insurmountable obstacles, but, when these are overcome, one has the satisfaction of having won over tremendous odds.

References

(1) R. G. Linderman, C. W. Handley, and A. Rodgers, "Illumination in motion picture production," *Jour. SMPE*, vol. 40, p. 333; June, 1943.

(2) Eastman Kodak Company pamphlet, *Kodachrome Commercial Film Type 5268.*

Television Test Film

With the expansion of commercial television operation at the close of the war there arose a need for detailed information on the production and use of films in television broadcasting. The Television Committee undertook to meet this need by approaching the problem from two directions.

First, they compiled information on what was believed to be good practice in the production of television films; and second, they provided the television broadcasters with a means of adjusting their film camera chains to best reproduce these films.

The first step in this combined project was completed in February, 1949, when the report "Films in Television" was published and distributed throughout both the television and motion picture industries.

The second phase of the work was completed in September, 1949, when a subcommittee under the chairmanship of Dr. R. L. Garman approved the television test film for release. Every effort was made by the subcommittee to incorporate in this film, which is now available to broadcast stations and equipment designers, the ideas and suggestions advanced by the television industry.

It is hoped that the adoption of the limits and procedures defined will aid the television broadcasters in raising the general quality level of film program transmission.

Purpose

The test film is designed to indicate the condition of operation of those portions of the television film reproduction system which depend upon the relation between the film projector and the television system.

Use of the test film on a routine operational basis is recommended since it will indicate errors of adjustment and equipment malfunction before they might otherwise be detected.

To facilitate making extended service adjustments, or to provide a suitable subject for the initial setup and adjustment of a film channel, there are available separate lengths of the alignment, low frequency, storage, and transfer characteristic sections. These sections may be cut into appropriate lengths, made into loops, and run continuously as the need arises.

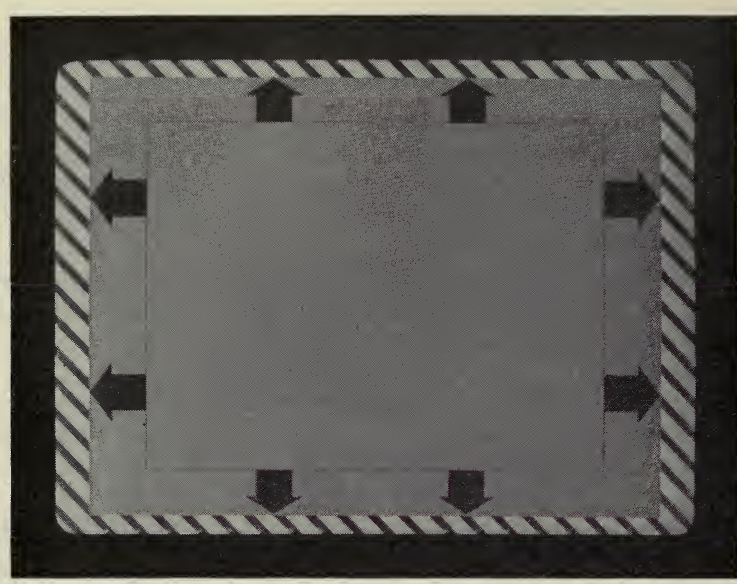


Figure 1

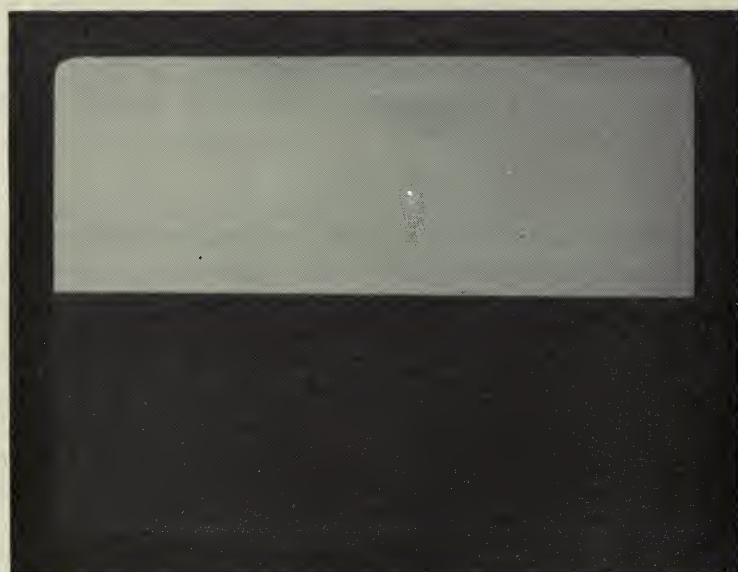


Figure 2

The film is not intended to be a laboratory instrument, although it may be useful in product design and test.

Contents

Seven test sections and a selection of scenes comprise the complete film which is available in either 16- or 35-mm widths. The test section is a series of geometrical patterns intended to present information on the factors most likely to be degraded in television film reproduction. Each chart selects some particular failing of the average system and produces a signal intended to exaggerate and thus clearly define any deviation from normal operation. Perfect reproduction of all the charts is to be desired, but some degradation of each is to be expected. Experience will show the magnitude of these effects which may be considered normal for any particular system.

Scenes representative of many types of pictures encountered in television films are included in the reel as a final qualitative test of over-all results.

Sec. 1. Alignment (See Fig. 1)

This pattern defines the portion of the projected film frame which is to be reproduced by the television system and permits accurate alignment of the motion picture projector with the television camera. Eight arrow points have been positioned to touch the edges of the picture area to be scanned. This area is smaller than that of the whole frame. One and a half per cent of the projected aperture is cut at top and bottom of the frame to allow for small drifts in scanning and centering. The horizontal dimension is chosen to provide a standard four-to-three aspect ratio with the established height. All of the frame area beyond these limits has been striped with a "barber-pole" effect. This striping must not appear in the television picture.

It should be noted that the striped area is wider on the sides of the frame than on the top and bottom. This results from the fact that the standard projection aperture does not have a four-to-three ratio but is wider by some 3%. See the American Standards for Picture Projection Apertures, Z22.58-1947 and Z22.8-1950.

Each vertical arrow head is 4% of the picture height and each horizontal arrow head is 4% of the picture width. Similarly, the arrow shanks are 6% of the picture height and width respectively.

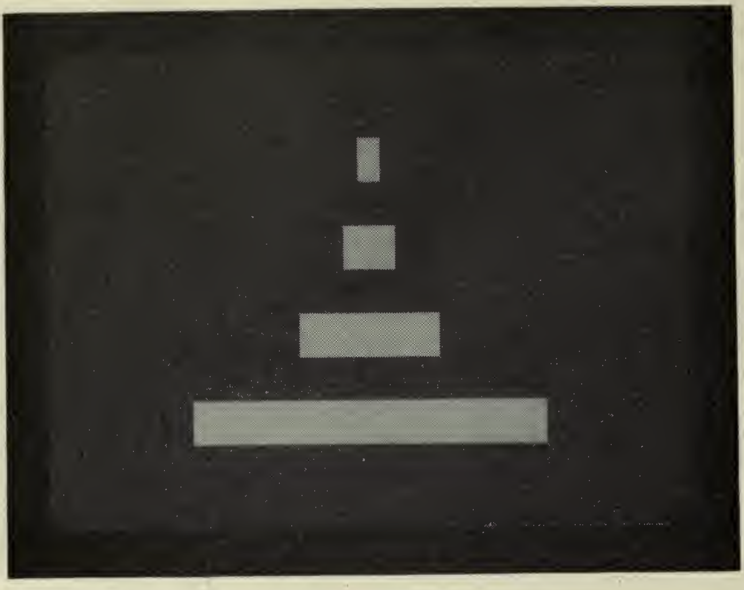


Figure 3

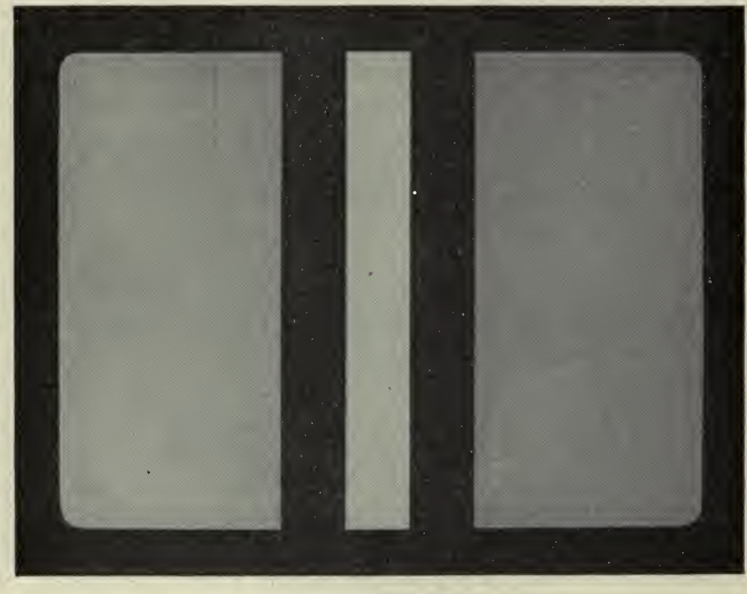


Figure 4

These dimensions permit rough estimates of the magnitude of scanning irregularities or misalignment through visual comparison of the effects in question with the size of the arrows. Specific values for misalignment obtained in this manner can be logged easily for future reference as part of a quality control program.

A rectangle formed by the lines connecting the arrow shanks encloses 80% of the active picture area. Investigation indicates that this area is reasonably well reproduced on most home receivers, even in the presence of scanning drift, inaccurate adjustment, and abnormal masking. No standard is implied but a general memory of this area may be useful in the preparation of film carrying important information.

Sec. 2. Low-Frequency Response (See Fig. 2)

This test is made in two parts, each consisting of a half-black–half-white frame, with the dividing line horizontal. The first section has the black portion at the top of the frame and the second is black at the bottom. These charts produce 60-cycle square wave signals. When viewed on the wave-form monitor set for field rate deflection, the signals should appear reasonably square. Serious tilting or bowing indicates incorrect low-frequency phase and amplitude response. When the system has been set for reproducing the first chart, the change to the second chart should not necessitate large shading changes.

The chart which is black at the bottom also permits a check on the amount of flare encountered in Iconoscope operation. Rim lights and beam current should be reset if the flare is excessive.

Sec. 3. Medium-Frequency Response (See Fig. 3)

The response of the television system to medium-frequency signals is of importance to picture quality. In this test, horizontal bars are used, first as black on white and then reversed. The bars have lengths equal in time of scanning beam travel to 2, 5, 12½, and 32 microseconds. These correspond to half-wave pulses covering an approximate fundamental frequency range from 15 to 250 kilocycles. Correct medium-frequency phase and amplitude response will be indicated by leading and trailing edges of the bars having no long, false gray tones. If, following the trailing edge of a bar, a streak appears having a tone similar to that of the bar (white after white, black after black) then it is reasonable to assume

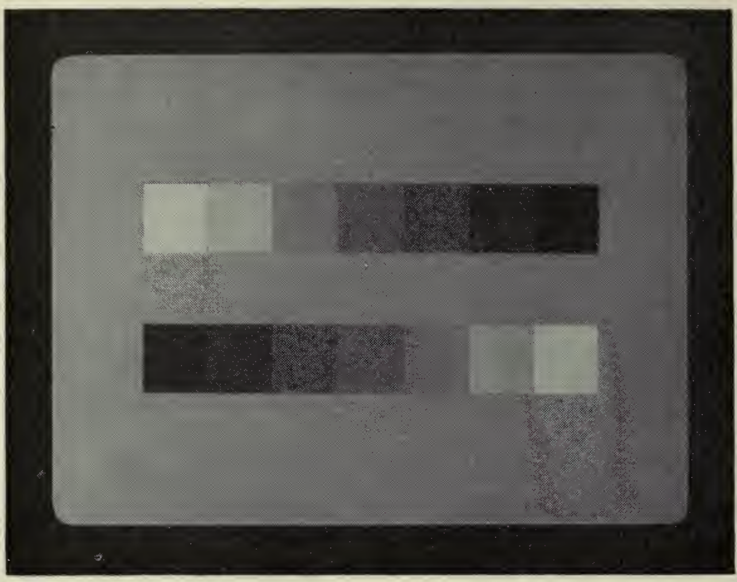


Figure 5

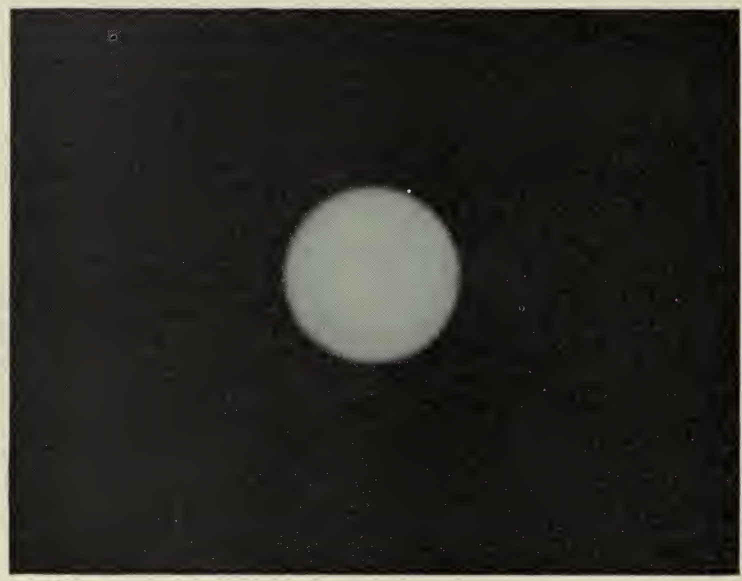


Figure 6

that the amplitude of the frequency represented by that bar is too great, or that its relative phase is incorrect. If the opposite occurs, as a white streak after a black bar, the fundamental frequency is too low in amplitude, and its relative phase is in error.

Sharp transient effects immediately following all bars are an indication of excessive high-frequency response. This condition will usually be clearly indicated in the test for resolution later in the film.

If very long streaking occurs in which the spurious signals are seen on the left side of the bars, as well as on the right, an investigation of the low-frequency response of the system should be made. Under these conditions close examination of the previous charts should reveal errors of wave form.

It is rarely possible to obtain perfect streaking-free reproductions of both the black-on-white and the white-on-black charts with one setting of the controls. This may be due, with Iconoscope operation, to the effects of wall sensitivity. A change in bias-light is usually required to compensate the charts exactly since the two charts do not have the same average transmission. The settings which produce very small streaking equally on both charts are usually preferred.

Sec. 4. Storage (See Fig. 4)

Film pickup systems which utilize short pulses of light must store the charge produced by the pulse long enough to permit the charge image to be scanned. Since the beam starts the scanning process at the top of the picture, the storage time required is maximum at the bottom of the picture. Some pickup tubes will suffer from leakage to the extent that the charge image may be seriously reduced in amplitude by the time the beam reaches the bottom of the picture.

The chart which checks this characteristic is made up of vertical black and white stripes on a gray background. When viewed on the wave-form monitor (set at field rate) this pattern will produce three lines representing white, gray, and black. Shading should be set to hold the gray line parallel with the blanking axis. If the white and black lines then tend to converge, the pickup tube does not have perfect storage. Perfect results are indicated when all traces are parallel. If the black-to-white amplitude at the bottom of the picture is divided by that at the top of the picture, the tube's storage factor is obtained. This is usually expressed in percentage.

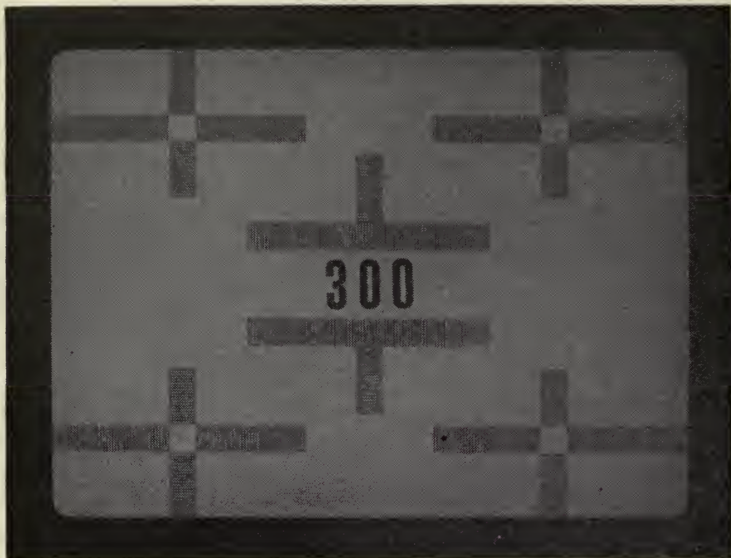


Figure 7

Figure 8

Sec. 5. Transfer Characteristics (*See Fig. 5*)

The ability of a television system to reproduce shades of gray is indicated in this section through the use of step-density areas. The first chart consists of a white area and a black area that serve as limit references, along with a centrally placed window in which the density steps appear.

The neutral gray background of this chart should be shaded flat and contrast and brightness settings adjusted to give normal wave-form monitor amplitudes from the reference areas mentioned. The wave-form monitor should be set for line frequency. Once adjusted, all settings should remain untouched during the remainder of the period. In the center window, a total of seven density tabs will appear labeled A through G. These will be seen in groups of three, as ABC, BCD, CDE, etc. This permits all steps to be read on the same portion of the mosaic and independently of shading and black spot. Each step should be visually compared with the adjacent steps, both in the picture and on the wave-form monitor, and each should be clearly defined. Saturation effects will be seen as a cramping together of adjacent steps. Experience as to the appearance of the tabs will establish a norm from which variations can be noted.

The final chart in this section consists of two step density tablets showing all seven steps together. The direction of progression of the second tablet is opposite to the first. These permit rapid over-all check.

The effective transfer characteristic of a film pickup system is a function of both film density and projected illumination. This test film has a range considered to represent that normally encountered in practice. If significant compression occurs, projector brightness should be checked. Other factors, including beam current, bias-light, and clipper adjustments should be tested with a stationary slide.

Sec. 6. Automatic Brightness Control (*See Fig. 6*)

This test indicates the ability of the television system to follow changes in average illumination of a series of scenes. It consists of a white disk centered in a black frame which enlarges slowly to fill the whole frame. As the white portion becomes larger, the brightness control should hold the black level constant. On the wave-

form monitor, the black signals should remain fixed in position relative to the blanking level. The first brightness changes on the film are both slow and even, so that systems with slow-acting control should be able to follow them accurately.

The second portion of the tests consists of sudden changes in white disk size from the smallest to one-third frame area and then to two thirds of the frame area. Experience will show how much error in black level setting results in these cases on a transient basis.

Sec. 7. Resolution (See Fig. 7)

Each of the five charts in this section is carefully calibrated to indicate the over-all system response at the number of lines printed in its center. Starting at 200 lines, the charts change at five-second intervals until the 600-line pattern appears. Each chart permits reading the response at six points within the frame. Care should be taken to note the response at the edges, as well as the center, of the picture.

Under abnormal conditions of "lateral leakage," resolution of a stored-charge picture degrades with time. This condition can be evaluated by noting the relative top and bottom resolution. If there is significant difference between the two, the system should be checked with a continuously illuminated slide. If the slide test shows the same resolution at both top and bottom and the film test does not, the pickup tube may be at fault.

The above presupposes that the projector has been properly tested for its inherent resolution with the visual test films available for that purpose.

Sec. 8. Typical Scenes (See Fig. 8)

To provide a qualitative check on the over-all results to be expected from good film, several scenes taken from material used specifically for television are included in the test reel. Utilization of this section will depend upon the operator's experience in judging acceptability and upon his memory of "how they looked before."

Recommendations for 16-Mm and 8-Mm Sprocket Design

Two major points affecting film life in 16-mm and 8-mm projectors are the shape of the film path entering and leaving the sprocket and the shape of the sprocket tooth. The following recommendations, approved by the Society, have been developed to assist the design engineer in specifying these, as well as other dimensions for particular applications.

INTRODUCTION

At a meeting held on December 16, 1948, the Committee on Standards approved a recommendation made by its subcommittee on sprockets to rescind the existing standards on 16-mm and 8-mm sprockets because they were not flexible enough to take care of such variables as the shape of the path of the film as it enters and leaves the sprocket, and the shape of tooth required for sprockets of different diameters. These standards were Z22.6-1941 and Z22.18-1941, respectively. Sectional Committee Z22 of the American Standards Association has affirmed this action.

There will be no American Standards to replace these two standards for some time. However, the Committee on Standards has concluded that the valuable information in the Chandler, Lyman, and Martin paper[1] will lead to sprocket designs giving superior performance. This material provides, for any application, a flexible means of designing sprockets that will transfer the load of the film smoothly from one tooth to the next, thereby materially lengthening the life of the film and decreasing flutter.

There are several reasons why this information is not ready for approval as an American Standard. These include:

(1) The committee has emphasized that two of the dimensions, *K* and *B*, which determine the final shape of the tooth, depend on the outcome of extensive tests to show which shape results in the longest film life.

(2) Some manufacturers are reluctant to abandon the shape given in previous standards or by their own designers because they have found it to be successful for the particular sizes of sprocket they are using.

(3) There has been disagreement among the members of the committee about whether standards should be written merely to insure interchangeability of parts or whether they should be based on affording optimum performance. These particular proposals are definitely in the latter class.

Some of the preceding viewpoints were expressed clearly by E. W. Kellogg.[2]

In view of the foregoing, the Committee has authorized the following abridgement of the Chandler, Lyman, and Martin paper, with additional data on 8-mm sprockets, printed in a form suitable for inclusion in the SMPTE Standards binder and entitled "Recommendations for 16-mm and 8-mm Sprocket Design." The purpose is to give the information a more official status than that of a paper in the Journal.

RECOMMENDATIONS

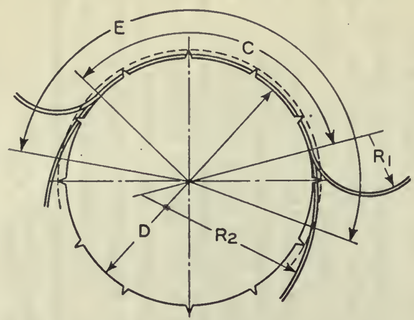
In October, 1945, Committee Z22 of the American Standards Association referred back to the Committee on Standards of the Society of Motion Picture Engineers, Standards Z22.6-1941 and Z22.18-1941 covering 16-mm and 8-mm film sprockets, respectively. They were returned with the suggestion that the substitution of formulas for the specific dimensions given in the original standards would afford the designer a more flexible means of meeting the requirements of each particular application. The Chairman of the Committee on Standards appointed a subcommittee to

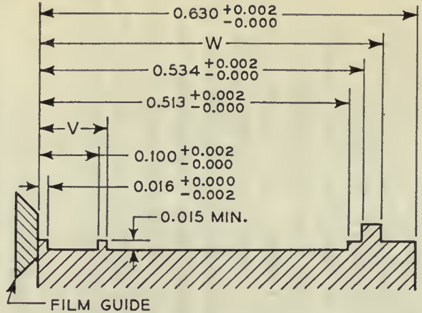
[1] **J. S. Chandler, D. F. Lyman, and L. R. Martin,** Proposals for 16-mm and 8-mm sprocket standards. *Jour. SMPE,* vol. 48, pp. 483–520; June, 1947.

[2] **E. W. Kellogg,** Discussion by letter. *Jour. SMPE,* vol. 51, pp. 437–440; October, 1948.

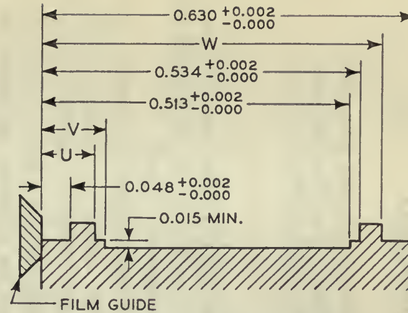
Approved: For a year's trial and criticism by the SMPTE Standards Committee, February 1, 1950.

Fig. 1. Design of Sprockets for 16-mm Film.

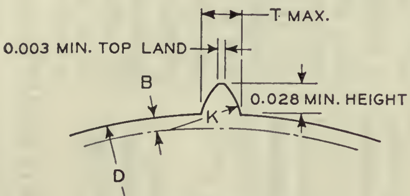




RECOMMENDED LATERAL PROFILE
FOR ALL EQUIPMENT



ALTERNATE LATERAL PROFILE
FOR SILENT EQUIPMENT ONLY



SHAPE OF TOOTH

	Dimension U	Dimension V	Dimension W
Camera	0.095	0.114	0.574
Projector	0.094	0.113	0.570
Tolerance	+0.000 −0.002	+0.000 −0.002	+0.000 −0.002

NOTE: All dimensions are in inches.

NOMENCLATURE

N Number of teeth on one end of sprocket.

H Number of film pitch lengths in direct contact with root diameter of the sprocket. $H = C \times N/360$ where C is the corresponding angle of contact in degrees.
H can be obtained by observation, but should be estimated to the nearest quarter of a pitch length.

F Number of film pitch lengths between the intersections of the path of the film and the path of the tip of the teeth. $F = E \times N/360$ where E is the corresponding angle of engagement in degrees.
F can be obtained by observation, but should be estimated to the nearest quarter of a pitch length.

S_{max} Per cent maximum film shrinkage to be accommodated. (Express as a decimal in the formulas.)

S_{min} Per cent minimum film shrinkage to be accommodated. (Express as a decimal in the formulas.) If stretch is to be considered, treat it as negative shrinkage.

T_{max} Maximum thickness of tooth in inches at root diameter.
Minimum permissible tooth thickness is controlled by minimum height (0.028 in.) and minimum top land (0.003 in.).

P Pitch of teeth in inches on the pitch circle at the center of the film thickness.

D Diameter in inches of the surface on which the film lies. (This may be a part of the sprocket or a separate guiding surface.) The tolerance for D equals the tolerance for P times N/π.

R_1 Minimum radius of film path entering or leaving the sprocket if path is curved away from the sprocket. Minimum $R_1 = 1/4$ in.

R_2 Minimum radius of film path entering or leaving the sprocket if path is curved toward the sprocket. Minimum $R_2 = 0.7D$.

K Radius of tooth.

B Distance from root diameter (D) to center for radius of tooth.

FORMULAS AND EXAMPLES

Formulas for computation of P, D, T, K, and B for drive, holdback, and combination sprockets. The examples are sample computations for a 12-tooth sprocket to accommodate film from 0.2 per cent stretch to 1.5 per cent shrinkage with H = 3.2 and F = 4.5 pitch lengths.

FORMULAS	*Tolerances*	*EXAMPLES*
Drive Sprocket		
$P = 0.300(1 - S_{min})$	$^{+0.0003}_{-0.0000}$	$P = 0.300(1 + 0.002) = 0.3006\ ^{+0.0003}_{-0.0000}$
$D = \frac{P \times N}{\pi} - 0.006$		$D = \frac{0.3006 \times 12}{\pi} - 0.006 = 1.142\ ^{+0.001}_{-0.000}$
$T_{max} = 0.050 - 0.15(H + F)(S_{max} - S_{min} + 0.001)$		$T_{max} = 0.050 - 0.15(3.2 + 4.5)(0.015 + 0.002 + 0.001) = 0.029$
Holdback Sprocket		
$P = 0.300(1 - S_{max})$	$^{+0.0000}_{-0.0003}$	$P = 0.300(1 - 0.015) = 0.2955\ ^{+0.0000}_{-0.0003}$
$D = \frac{P \times N}{\pi} - 0.006$		$D = \frac{0.2955 \times 12}{\pi} - 0.006 = 1.123\ ^{+0.000}_{-0.001}$
$T_{max} = 0.050 - 0.15(H + F)(S_{max} - S_{min} + 0.001)$		$T_{max} = 0.050 - 0.15(3.2 + 4.5)(0.015 + 0.002 + 0.001) = 0.029$
Combination Sprocket		
$P = 0.300 - 0.2S_{min} - 0.1S_{max}$	$^{+0.0003}_{-0.0000}$	$P = 0.300 + 0.2(0.002) - 0.1(0.015) = 0.2989\ ^{+0.0003}_{-0.0000}$
$D = \frac{P \times N}{\pi} - 0.006$		$D = \frac{0.2989 \times 12}{\pi} - 0.006 = 1.136\ ^{+0.001}_{-0.000}$
$T_{max} = 0.050 - 0.1(H + F)(S_{max} - S_{min} + 0.001)$		$T_{max} = 0.050 - 0.1(3.2 + 4.5)(0.015 + 0.002 + 0.001) = 0.036$
For All Sprockets		
$K = 0.111 - \frac{0.45}{N} + \frac{1}{N^2}$	$^{+0.000}_{-0.002}$	$K = 0.111 - \frac{0.45}{12} + \frac{1}{144} = 0.0804\ ^{+0.000}_{-0.002}$
$B = (0.025 + S_{max} - S_{min})\left(0.98 - \frac{4}{N} + \frac{10}{N^2}\right) - 0.014$	$^{+0.0005}_{-0.0000}$	$B = (0.025 + 0.015 + 0.002)\left(0.98 - \frac{4}{12} + \frac{10}{144}\right) - 0.014 = 0.016\ ^{+0.0005}_{-0.0000}$

After computing T, K, and B, check for minimum height and top land on large scale layout. If necessary, change film path to reduce H and F in order to obtain thicker tooth.

For Appendix to Fig. 1, see p. 223.

prepare new standards.* It was for that subcommittee that these recommendations were outlined.

Figures 1 and 2 are the recommendations for 16-mm and 8-mm sprockets, respectively. Provision has been made for camera, printer, and projector sprockets having any practicable number of teeth. Particular attention has been given to the shape of the film path and to the lateral profile of the sprocket itself and also to the lateral profiles of guides, rollers, and film gates.

For simplicity of illustration, the film is often shown entering and leaving the sprocket in straight lines tangent to the root diameter, but by far the more usual path is a curve, either away from the sprocket or toward the sprocket. A minimum of ¼ inch is proposed for R_1, the radius of the path that curves *away* from the sprocket. The proposed value of $0.7D$ for R_2, the minimum radius when the film is curved *toward* the sprocket, is derived analytically.

Accommodation for changes in film caused by shrinkage is the principal factor in the design of sprockets. There are two reasons why this accommodation is necessary: (1) the film must not be damaged prematurely by the sprocket (this is important for projection equipment in which the same film may be run many times), and (2) on sound and printing sprockets, the film must run at a relatively constant velocity in order to ensure freedom from flutter. Fortunately, it is possible to design for good results in both respects.

Three aspects of sprocket design for which the potential shrinkage of the film must be taken into account are: (1) the circular pitch of the teeth, (2) the shape and thickness of the teeth, and (3) the lateral profile of the sprocket.

Circular Pitch of the Teeth

The circular pitch of the sprocket teeth can be made longer or shorter than the pitch of the film. Only in rare cases will the pitches be equal. The choice depends largely upon the type of service expected from the sprocket.

Types of Sprockets. In motion picture equipment there are two basic types of sprockets. With the first type, the film is urged forward against backward tension, and the sprocket is a drive sprocket. The second type is the take-up or holdback sprocket. Here both the motion and the tension are forward; hence the film is held back by the sprocket.

The important rules for drive and holdback sprockets are:

(1) A properly designed *drive* sprocket should have a circular pitch *equal to or greater than* the pitch of the film.

(2) A properly designed *holdback* sprocket should have a circular pitch *equal to or less than* the pitch of the film.

These rules, upon which the formulas of the recommendations are based, are so chosen that all slippage between the film and the sprocket is in the same direction as the tension on the film. Thus any friction between the film and the base of the sprocket serves to assist in the functioning of the sprocket rather than to increase the load between the film and the teeth. Also according to the rules, the leaving tooth is the one that does the work of driving the film or holding it back. There is, therefore, clearance between the entering tooth and its mating perforation, as long as the thickness of the teeth is such as to avoid interference.

In addition, there is the combination sprocket, which is often used in reversible apparatus where the function of the sprocket changes as the direction of motion changes. Also, in many cameras and in some projectors, one section of a single sprocket serves as a drive sprocket and another section as a holdback sprocket. Moreover, the function of a sprocket may change owing to the varying tension exerted by the take-up, or for other reasons. Combination sprockets are not recommended for precision apparatus such as printers or other professional equipment.

The optimum pitch for a combination sprocket is a compromise, at best. If a prop-

* **O. Sandvik (Chairman), H. Barnett, J. A. Maurer, L. T. Sachtleben, and M. G. Townsley.**

erly designed drive sprocket is used as a combination sprocket, all film operating under holdback conditions is forced against the direction of external tension by each tooth as it enters the perforation. The same is true of a holdback sprocket operating under drive conditions. Experience has shown that unless special attention is given to guiding the film as it engages the sprocket, a drive sprocket makes a poorer combination sprocket than does a holdback sprocket. Therefore, the combination sprocket was designed to favor its action when it is driving film; its pitch matches that of film having a shrinkage equal to the minimum shrinkage plus one-third (instead of plus one-half) the shrinkage range for which accommodation is being made.

Shape and Thickness of Sprocket Teeth

Importance of Shape of Tooth. In all cases except that of perfect mesh there must be some sliding of the edge of the perforation up or down the face of the tooth. The shape of the tooth is important not only from the standpoint of wear of the film at the point of contact, but also as it relates to the sliding of the film along the root circle of the sprocket and to the manner of transfer of the load from one tooth to the next. In the worst case, all the shrinkage differential is absorbed by a sudden jump of the film as it leaves the tip of one tooth and comes into contact with the next tooth.

APPENDIX TO FIG. 1

These recommendations for film sprocket design have been developed to give the design engineer an opportunity to specify sprocket dimensions for particular applications and conditions. They consist of a number of simple formulas for the computation of tooth thickness, tooth shape, and circular pitch based upon the range of film shrinkage to be accommodated and the amount of contact between film and sprocket. The root diameter on which the film will run is computed from the circular pitch and the number of teeth on one end of the sprocket.

In cases where the film pitch does not match the sprocket pitch, the formulas for the sprocket pitch are such that the slippage of the film will be in the direction of external tension on the film, backward on feed or drive sprockets, and forward on holdback sprockets.

The optimum pitch of the combination sprocket has been established to specify a sprocket that meshes perfectly with film having a shrinkage of the minimum shrinkage plus one third of the shrinkage range. Film of less shrinkage is forced against the direction of the external tension when this sprocket is operating as a drive sprocket. Film of greater shrinkage is forced against the direction of external tension when this sprocket is operating as a holdback sprocket. Combination sprockets should be avoided wherever possible.

It will be noted that formulas for the maximum permissible tooth thickness involve the use of fractions of a film pitch length. (See definitions for H and F.) This provides clearance for the teeth in partial engagement with the film.

The shape determined by dimensions K and B provides clearance at the tip of the leaving tooth for paths between R_1 and R_2. For sound and printing sprockets optimum conditions of flutter are obtained when the film path curves toward the sprocket and approaches the limit defined by R_2. A more precise formula for R_2 for sound and printing sprockets is $1/R_2 = 19/N - 26/N^2 - 0.060$. The sprocket in this case should be designed and used as a drive sprocket. If it is necessary to use a sound sprocket as a holdback sprocket, it should be designed as a drive sprocket, and film guides must be provided to force the film onto the teeth.

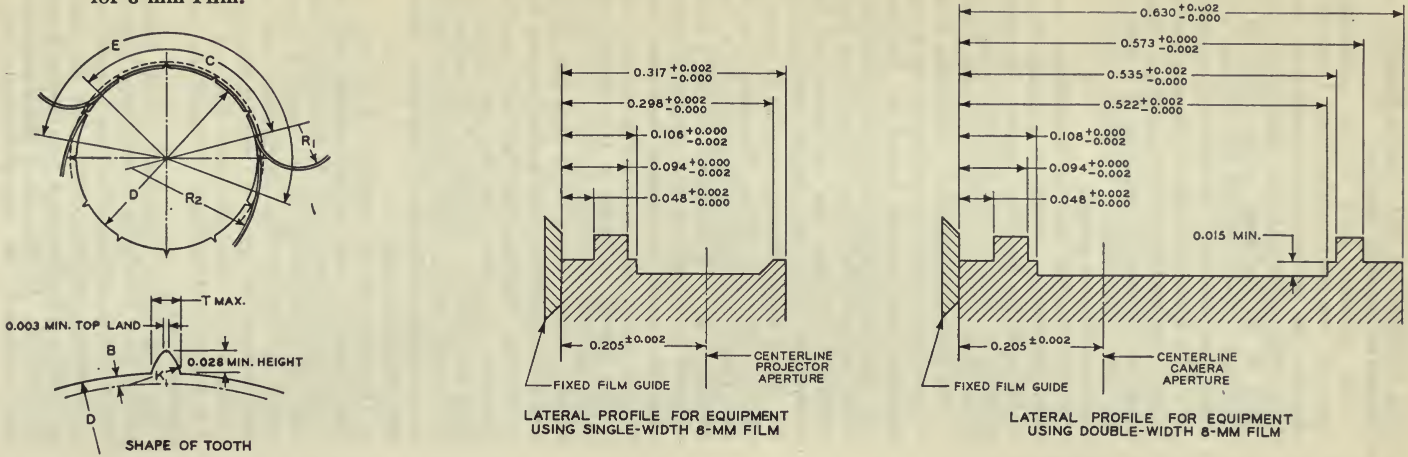
The dimensions shown in the lateral profile views provide clearance for film with lateral shrinkage from 0 to 1.0 per cent for cameras and from 0 to 1.8 per cent for projectors. Film of greater shrinkage can be used on these sprockets, but either the film will pull away from the guide or the fillet of the perforation will engage with the tooth. These lateral dimensions are applicable also to film gates, guides, and pull-down claws.

The choice by the engineer of the range of film shrinkage to be accommodated must depend upon the experience of the manufacturer and the type of equipment being designed. Based on current film conditions, suggested ranges would be from 0 to 1 per cent shrinkage for equipment using unexposed film and from 0 to 1.5 per cent shrinkage for equipment using processed film.

In most cases, particularly when tensions greater than 2 oz must be overcome, it is desirable to make H at least two film pitch lengths. An exception to this occurs when the film is positively guided through a path curving toward the sprocket. In this case, if the value of F is high—at least 4—the value of H may be zero.

Fig. 2. Design of Sprockets for 8-mm Film.

NOTE: All dimensions are in inches.



NOMENCLATURE

- *N* Number of teeth on one end of sprocket.
- *H* Number of film pitch lengths in direct contact with root diameter of the sprocket. $H = C \times N/360$ where C is the corresponding angle of contact in degrees.
  H can be obtained by observation, but should be estimated to the nearest quarter of a pitch length.
- *F* Number of film pitch lengths between the intersections of the path of the film and the path of the tip of the teeth. $F = E \times N/360$ where E is the corresponding angle of engagement in degrees.
  F can be obtained by observation, but should be estimated to the nearest quarter of a pitch length.
- S_{max} Per cent maximum film shrinkage to be accommodated. (Express as a decimal in the formulas.)
- S_{min} Per cent minimum film shrinkage to be accommodated. (Express as a decimal in the formulas.) If stretch is to be considered, treat it as negative shrinkage.
- T_{max} Maximum thickness of tooth in inches at root diameter.
  Minimum permissible tooth thickness is controlled by minimum height (0.028 in.) and minimum top land (0.003 in.).
- *P* Pitch of teeth in inches on the pitch circle at the center of the film thickness.
- *D* Diameter in inches of the surface on which the film lies. (This may be a part of the sprocket or a separate guiding surface.) The tolerance for D equals the tolerance for P times N/π.
- R_1 Minimum radius of film path entering or leaving the sprocket if path is curved away from the sprocket. Minimum $R_1 = 1/4$ in.
- R_2 Minimum radius of film path entering or leaving the sprocket if path is curved toward the sprocket. Minimum $R_2 = 0.7D$.
- *K* Radius of tooth.
- *B* Distance from root diameter (D) to center for radius of tooth.

FORMULAS AND EXAMPLES

Formulas for computation of P, D, T, K, and B for drive, holdback, and combination sprockets. The examples are sample computations for a 12-tooth sprocket to accommodate film from 0.2 per cent stretch to 1.5 per cent shrinkage with $H = 2.5$ and $F = 3.5$ pitch lengths.

FORMULAS	*Tolerances*	*EXAMPLES*
Drive Sprocket		
$P = 0.150(1 - S_{min})$	$^{+0.0003}_{-0.0000}$	$P = 0.150(1 + 0.002) = 0.1503\ ^{+0.0003}_{-0.0000}$
$D = \dfrac{P \times N}{\pi} - 0.006$		$D = \dfrac{0.1503 \times 12}{\pi} - 0.006 = 0.568\ ^{+0.001}_{-0.000}$
$T_{max} = 0.050 - 0.075(H + F)(S_{max} - S_{min} + 0.002)$		$T_{max} = 0.050 - 0.075(2.5 + 3.5)(0.015 + 0.002 + 0.002) = 0.041$
Holdback Sprocket		
$P = 0.150(1 - S_{max})$	$^{+0.0000}_{-0.0003}$	$P = 0.150(1 - 0.015) = 0.1478\ ^{+0.0000}_{-0.0003}$
$D = \dfrac{P \times N}{\pi} - 0.006$		$D = \dfrac{0.1478 \times 12}{\pi} - 0.006 = 0.559\ ^{+0.000}_{-0.001}$
$T_{max} = 0.050 - 0.075(H + F)(S_{max} - S_{min} + 0.002)$		$T_{max} = 0.050 - 0.075(2.5 + 3.5)(0.015 + 0.002 + 0.002) = 0.041$
Combination Sprocket		
$P = 0.150 - 0.1S_{min} - 0.05S_{max}$	$^{+0.0003}_{-0.0000}$	$P = 0.150 + 0.1(0.002) - 0.05(0.015) = 0.1494\ ^{+0.0003}_{-0.0000}$
$D = \dfrac{P \times N}{\pi} - 0.006$		$D = \dfrac{0.1494 \times 12}{\pi} - 0.006 = 0.565\ ^{+0.001}_{-0.000}$
$T_{max} = 0.050 - 0.05(H + F)(S_{max} - S_{min} + 0.002)$		$T_{max} = 0.050 - 0.05(2.5 + 3.5)(0.015 + 0.002 + 0.002) = 0.044$
For All Sprockets		
$K = 0.111 - \dfrac{0.9}{N} + \dfrac{4}{N^2}$	$^{+0.000}_{-0.002}$	$K = 0.111 - \dfrac{0.9}{12} + \dfrac{4}{144} = 0.064\ ^{+0.000}_{-0.002}$
$B = (0.05 + S_{max} - S_{min})\left(0.49 - \dfrac{4}{N} + \dfrac{20}{N^2}\right) - 0.014$	$^{+0.0005}_{-0.0000}$	$B = (0.05 + 0.015 + 0.002)\left(0.49 - \dfrac{4}{12} + \dfrac{20}{144}\right) - 0.014 = 0.006\ ^{+0.0005}_{-0.0000}$

After computing T, K, and B, check for minimum height and top land on large scale layout. If necessary, change film path to reduce H and F in order to obtain thicker tooth.

In general, both the Nomenclature and the Appendix apply to 16-mm and 8-mm sprockets, but there are the following minor exceptions:

(1) The reference to sound sprockets in the fifth paragraph of the Appendix will not ordinarily apply to 8-mm sprockets, but there may be some interest in sprockets for printers. For such applications, a conservative formula for the optimum value of R is given by $\dfrac{1}{R_2} = \dfrac{38}{N} - \dfrac{104}{N^2} - 0.060$.

(2) In this case, the dimensions shown in the lateral profile views, which are mentioned in the sixth paragraph, provide clearance for a lateral shrinkage range of 0 to 1.5 per cent.

It will be obvious from a study of the nature of the action of the tooth that the drive sprocket is the most critical with respect to the shape of the tooth.

Epicycloid Curve. The most logical starting place for the analysis of the shape of the tooth is the curve generated by a point on the film relative to the sprocket when the film moves along its path without slipping on the root circle of the sprocket. Since we have assumed that the path is an arc of a circle, the curve so generated is an epicycloid. In the case of a straight path, the resulting curve is an involute and can be treated as a special case of the epicycloid in which the generating circle has an infinite radius. The generated curve is an epicycloid whether the generating circle curves away from the sprocket or curves toward the sprocket and actually encloses it. (Equations to aid in plotting the epicycloid are given in the complete paper.)

Since the epicycloid is generated by a circle rolling on the root circle, it is the locus, relative to the sprocket, of a point on the film, such as the edge of a perforation, provided there is no slippage between the film and the sprocket. The epicycloid curve is a valuable reference from which the desired shape of the tooth can be deduced by proper allowance for the amount of film shrinkage to be accommodated.

It is obvious that the reference epicycloid to consider is the one that corresponds to the most limiting condition, namely, the film path that curves away from the sprocket along the arc with the minimum radius.

Allowance for Shrinkage at Tip of Tooth. Figure 3 shows on a large scale the film and one tooth of a 12-tooth sprocket for 16-mm film. If the tooth is moving to the left and the film tension is to the right, we have a drive sprocket. The circular pitch of the sprocket is greater than the pitch of the film.

If the shape of the tooth is such as to guide the film along the epicycloid (Fig. 3, curve 1) the film will not slip on the sprocket until after it leaves the tip of the tooth, whereupon it will jump to the right and will stop suddenly when the next perforation engages the next tooth to the right. A tooth shape falling to the right of the epicycloid will let the film slip gradually and thus accommodate part of, or all, the shrinkage differential before the film reaches the tip of the tooth. The optimum condition is reached when the tooth just allows accommodation of the maximum shrinkage differential when the film is ready to leave the tip of the tooth. If the film is shrunk less, there will be full accommodation earlier and the film will leave the tooth before it reaches the top.

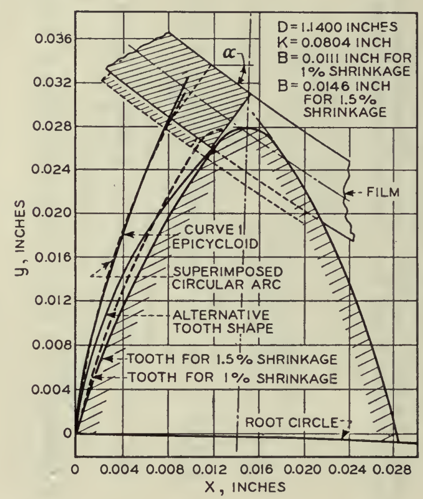


Fig. 3. Tooth Shape for 12-Tooth, 16-mm Sprocket.

The shrinkage differential with which we are concerned is that for one pitch length of film. For example, if the shrinkage range is from 0 to 1.5 per cent, the circular pitch of the sprocket is chosen to match unshrunk film (0.300 in.) and the maximum pitch differential is 1.5 per cent of 0.300 in., or 0.0045 in. The proposed tolerances for the pitch of the drive sprocket are plus 0.0003 in., minus 0.0000. Therefore, an additional allowance of approximately 0.0003 in. is made in establishing the location of the tip of the tooth.

Figure 3 shows two film positions, one in solid lines for a shrinkage of 1.5 per cent and one shown by broken lines for a shrinkage of 1 per cent. In each case the lower edge of the perforation is 0.026 in. above the root circle, and the film is just ready to leave the tooth.

Specification of Shape of Tooth. So far, only two points on the profile of the tooth have been located, one at the maximum working height of 0.026 in. and the other at the intersection with the root circle. Obviously, the manner in which the film is allowed to slip to take care of the shrinkage differential is controlled by the shape of the tooth between these two points. However, the relationship between the way the film slips and the running life of the film is not directly evident. The ultimate solution lies in exhaustive wear tests, with due consideration to all the other factors involved. A convenient method of specifying the shape of the tooth is to state the radius K of a circular arc and the distance B from the root circle to the center of the arc. (When B is positive, the center is inside the root circle.) This method is justified not only for its convenience but for practical considerations of manufacture. That the circular arc is adequate can be seen in Fig. 3 from the close agreement of the circular arc with the epicycloid. One logical procedure for defining the shape of the tooth has been completely worked out and is described here, followed by a brief discussion of an alternative procedure.

The first method is based on the circular arc that best approximates the epicycloid. As the shrinkage differential increases, the radius K of the tooth (Fig. 1) remains constant, but B, the distance from the root circle to the center of the radius, is increased. This brings the upper end of the tooth to the proper terminal point and provides a uniform shrinkage adjustment as the film moves up the face of the tooth.

It may be argued that the above procedure will result in a tooth that slants too much at its base for good driving action, particularly when the tension on the film is high. The alternative procedure for determining the shape of the tooth overcomes this objection. By this method, the value of B is made independent of the range of shrinkage and approximates the value given by the above equation for zero range of shrinkage. The value of K must then vary with the range of shrinkage, from about the value given above to lower values as more shrinkage is accommodated. The resulting tooth is very nearly tangent to the epicycloid at its base but never crosses to the left of the epicycloid. This gives the steepest permissible tooth at the base. Equations for this procedure have not been completely derived, but the shape for 1.5 per cent shrinkage on a 12-tooth, 16-mm sprocket is shown by a light line on Fig. 3. The running life of the film should be considered the most important criterion for the final choice. From the standpoint of flutter, there appears to be an advantage in the first procedure.

It is also possible to specify an involute (with a given pressure angle) for the shape of the tooth. This is not recommended because it results in a tooth which is even more slanting at its base than the tooth obtained by the first procedure.

Thickness of the Tooth at the Base. For the properly designed drive or holdback sprocket, the action of the tooth takes place at the end of the film path, where the tooth is leaving. For the cases of maximum differential between the pitch of the sprocket and that of the film, there may be interference at the entering tooth (at the outside face for drive sprockets and at the inside face for holdback sprockets) if proper attention is not given to the selection of the thickness of the tooth.

As given in the recommendations, the equations apply to the first procedure for determining the shape. The formula for the thickness of the tooth includes the following reductions from the full longitudinal dimension of the perforation: one for the shrinkage of the film in the arc of contact; a second for the teeth in partial engagement; a third for the pitch tolerance allowed for the sprocket; and

a fourth for positive clearance. If the tooth becomes too thin to provide the proper working height or the desired total height, the arc of contact or the arc of partial engagement, or both, must be shortened.

Other Considerations. One advantage of the equation form of the recommendations is its great flexibility. Suitable changes can readily be introduced to allow for the effects of stretch and distortion of the film. No attempt has been made in the present analysis to incorporate these alterations. It is felt that more precise quantitative information is needed and that any such proposed changes should be backed by thorough testing before their presentation. On the basis of test observations, for sprockets made according to the formulas of Fig. 1, it is recommended that the tension not exceed 4 oz for drive sprockets nor 8 oz for holdback sprockets.

The number of film pitch lengths in the arc of contact and in the arc of engagement has a bearing upon the operation of the sprocket, especially if appreciable amounts of distortion are present. For practical reasons the minimum recommended value of H has, therefore, been set at 2, except for the special conditions noted in the Appendix of Fig. 1.

Lateral Profile

Need of Specifying Lateral Profile. It is necessary to pay special attention to the lateral profile of sprockets in order to prevent the corners of the teeth from damaging the fillet of the perforation. Other zones to protect are the picture area and the sound-track area. The purpose, therefore, of specifying the lateral profile is to ensure that the tooth will be of the correct size and that it will be located properly in relation to the guide for the edge of the film. Moreover, it is necessary to locate the zones that are recessed or undercut below the root diameter so that the picture and sound-track areas will be protected.

Edge to Be Guided. Several conditions must be established before the dimensions can be determined. The first of these is the choice of the edge of the film to be guided. Figure 1 is based on a fixed guide at the sound-track edge of the film. This results in rails of adequate width at that edge, but it is necessary to restrict the lateral width of the tooth somewhat because the tooth is so far from the fixed guide. On the other hand, if the fixed guide were placed at the perforated edge of the film, the lateral width of the tooth could be made greater, but the rails would be extremely narrow, if they could be provided at all. Channel guiding is subject to the disadvantages of both systems in that the tooth must be narrow and it is almost impossible to specify guiding rails that will not scratch the sound track. Detailed tables for the three methods of guiding, and for sprockets with two rows of teeth, are given in the complete paper.

CONCLUSION

The principal advantages of these recommendations are their adaptability and their flexibility. They are adaptable to any application regardless of the size and the function of the sprocket and also of the path and the shrinkage of the film. They are flexible because they are presented in such form that if changes are made in the physical properties of film or if research discovers new conditions of improved operation, the formulas can be adjusted to keep the recommendations up to date.

NOTE: C. F. Vilbrandt supervised actual running tests with different types of sprockets and reported his preliminary findings.[3] His report is of interest for two reasons: (1) it describes the action of the various sprockets with films of different pitches; and (2) it indicates a method of testing that correlates the life of the film with the differential pitch, and with the tension to which the film is subjected. Further testing of this kind should indicate the tooth shape that will provide the longest film life.

[3] C. F. Vilbrandt, The projection life of 16-mm film. *Jour. SMPE*, vol. 48, pp. 521–542; June, 1947.

Proposed American Standard 16-Mm Projection Reels

THE PROPOSED STANDARD which appears on the following pages was prepared by the 16- and 8-Mm Motion Pictures Committee, under the Chairmanship of Mr. Henry Hood. Completely new in appearance, it replaces the previous American Standard for 16-Mm Projections Reels Z22.11-1941 and is being published here in the form of a proposal for ninety days trial and criticism. Engineers or equipment designers are invited to send their comments on the proposal to William H. Deacy, Jr., Staff Engineer at Society Headquarters, and are asked to do so before June 1, 1950.

The original 16-Mm Reel Standard, Z22.11, was found to be inadequate during the war and at that time an American War Standard, Z52.33-1945, was developed to provide the armed services with a more detailed set of specifications. At the end of the war, a subcommittee, under the chairmanship of Mr. D. F. Lyman, examined both the prewar and the wartime standards, with a view toward combining the best parts of each in a form that would be most useful to equipment designers and manufacturers. The project was subsequently transferred to the 16- and 8-Mm Motion Pictures Committee and this proposal is the formal recommendation of that Committee.

In developing this proposed standard, the Committee found that some of the dimensions and tolerances of the wartime standard were so rigid as to be commercially impractical and that it was necessary to take a more realistic point of view, since reels had to be manufactured in quantity and sold at a reasonable price. These considerations account in particular for the wide tolerances shown on the outside and core diameters. As indicated in the note following Table 2, the Committee has expressed a hope that reel manufacturers will adopt the dimensions recommended whenever they find it necessary to manufacture new production tools.

The only question not completely resolved in the many committee meetings required to develop this new proposal had to do with the shape of the spindle hole. One group favored the use of square holes in both flanges while another group recommended one square and one round hole. Consideration was also given to the possible alternative of using a keyway as defined by Dimensions U and V, that could be added to the round hole. The Committee feels that comments on this particular point would be very helpful.

Proposed American Standard

16-Millimeter Motion Picture Projection Reels

Z22.11

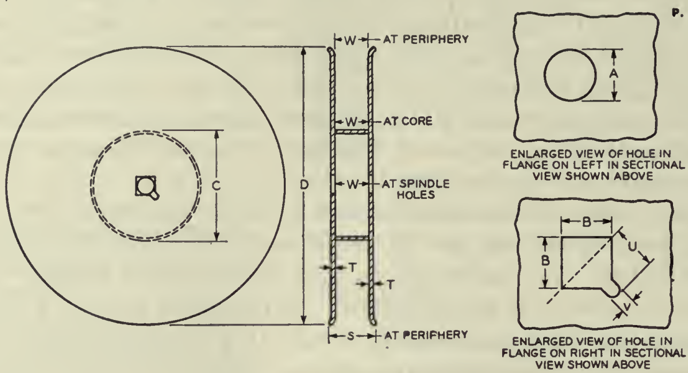


TABLE 1

Dimension	Inches	Millimeters
A	0.319 $^{+0.000}_{-0.003}$	8.10 $^{+0.00}_{-0.08}$
B	0.319 $^{+0.000}_{-0.003}$	8.10 $^{+0.00}_{-0.08}$
W, at periphery [1]	0.660 $^{+0.045}_{-0.025}$	16.76 $^{+1.14}_{-0.64}$
at core [2]	0.660 ±0.010	16.76 ±0.25
at spindle holes	0.660 ±0.015	16.76 ±0.38
T (exclusive of embossing)	0.027 minimum 0.066 maximum	0.69 minimum 1.68 maximum
S at periphery [3] (including flared, rolled, or beveled edges)	0.962	24.43 maximum
U	0.312 ±0.016	7.92 ±0.41
V	0.125 $^{+0.005}_{-0.000}$	3.18 $^{+0.13}_{-0.00}$
Flange and core concentricity [4]	±0.031	±0.79

See Notes on p. 3.

NOT APPROVED

Proposed American Standard

16-Millimeter Motion Picture Projection Reels

Z22.11

TABLE 2

Capacity	Dimension	Inches	Millimeters	Capacity	Dimension	Inches	Millimeters
200 Feet [5]	D, nominal	5.000	127.00	1200 Feet	D, nominal	12.250	311.15
(61 Meters)	maximum	5.031	127.79	(366 Meters)	maximum	12.250	311.15
	minimum	5.000	127.00		minimum	12.125*	307.98*
	C, nominal	1.750	44.45		C, nominal	4.875	123.83
	maximum	2.000*	50.80*		maximum	4.875	123.83
	minimum	1.750	44.45		minimum	4.625*	117.48*
	Lateral run-out,[6] maximum	0.570	1.45		Lateral run-out,[6] maximum	0.140	3.56
400 Feet [5]	D, nominal	7.000	177.80	1600 Feet	D, nominal	13.750	349.25
(122 Meters)	maximum	7.031	178.59	(488 Meters)	maximum	14.000*	355.60*
	minimum	7.000	177.80		minimum	13.750	349.25
	C, nominal	2.500	63.50		C, nominal	4.875	123.83
	maximum	2.500	63.50		maximum	4.875	123.83
	minimum	1.750*	44.45*		minimum	4.625*	117.48*
	Lateral run-out,[6] maximum	0.080	2.03		Lateral run-out,[6] maximum	0.160	4.06
800 Feet	D, nominal	10.500	266.70	2000 Feet	D, nominal	15.000	381.00
(244 Meters)	maximum	10.531	267.49	(610 Meters)	maximum	15.031	381.79
	minimum	10.500	266.70		minimum	15.000	381.00
	C, nominal	4.875	123.83		C, nominal	4.625	117.48
	maximum	4.875	123.83		maximum	4.875	123.83
	minimum	4.500*	114.30*		minimum	4.625	117.48
	Lateral run-out,[6] maximum	0.120	3.05		Lateral run-out,[6] maximum	0.171	4.34

NOT APPROVED

Proposed American Standard

16-Millimeter Motion Picture Projection Reels

Z22.11

P. 3 of 3 pp.

NOTES

* When new reels are designed, or when new tools are made for present reels, the cores and flanges should be made to conform, as closely as practicable, to the nominal values in the above table. It is hoped that in some future revision of this standard the asterisked values may be omitted.

[1] Except at embossings, rolled edges, and rounded corners, the limits shown here shall not be exceeded at the periphery of the flanges, nor at any other distance from the center of the reel.

[2] If spring fingers are used to engage the edges of the film, dimension W shall be measured between the fingers when they are pressed outward to the limit of their operating range.

[3] Rivets or other fastening members shall not extend beyond the surfaces of the flanges more than 1/32 inch (0.79 millimeters).

[4] This concentricity is with respect to the center line of the hole for the spindles.

[5] This reel should not be used as a take-up reel on a sound projector unless there is special provision to keep the take-up tension within the desirable range of 1½ to 5 ounces.

[6] Lateral runout is the maximum excursion of any point on the flange from the intended plane of rotation of that point when the reel is rotated on an accurate, tightly fitted shaft.

APPENDIX

Dimensions A and B were chosen to give sufficient clearance between the reels and the largest spindles normally used on 16-millimeter projectors. While some users prefer a square hole in both flanges for laboratory work, it is recommended that such reels be obtained on special order. If both flanges have square holes, and if the respective sides of the squares are parallel, the reel will not be suitable for use on some spindles. This is true if the spindle has a shoulder against which the outer flange is stopped for lateral positioning of the reel. But the objection does not apply if the two squares are oriented so that their respective sides are at an angle.

For regular projection, however, a reel with a round hole in one flange is generally preferred. With it the projectionist can tell at a glance whether or not the film needs rewinding. Furthermore, this type of reel helps the projectionist place the film correctly on the projector and thread it so that the picture is properly oriented with respect to rights and lefts.

The nominal value for W was chosen to provide proper lateral clearance for the film, which has a maximum width of 0.630 inch. Yet the channel is narrow enough so that the film cannot wander laterally too much as it is coiled; if the channel is too wide, it is likely to cause loose winding and excessively large rolls. The tolerances for W vary. At the core they are least because it is possible to control the distance fairly easily in that zone. At the holes for the spindles they are somewhat larger to allow for slight buckling of the flanges between the core and the holes. At the periphery the tolerances are still greater because it is difficult to maintain the distance with such accuracy.

Minimum and maximum values for T, the thickness of the flanges, were chosen to permit the use of various materials.

The opening in the corner of the square hole, to which dimensions U and V apply, is provided for the spindles of 35-millimeter rewinds, which are used in some laboratories.

D, the outside diameter of the flanges, was made as large as permitted by past practice in the design of projectors, containers for the reels, rewinds, and similar equipment. This was done so that the values of C could be made as great as possible. Then there is less variation, throughout the projection of a roll, in the tension to which the film is subjected by the take-up mechanism, especially if a constant-torque device is used. Thus it is necessary to keep the ratio of flange diameter to core diameter as small as possible, and also to eliminate as many small cores as possible. For the cores, rather widely separated limits (not intended to be manufacturing tolerances) are given in order to permit the use of current reels that are known to give satisfactory results.

NOT APPROVED

A Restatement of Policy

The Society of Motion Picture and Television Engineers is composed of technical representatives from all phases of the industries involved in the reproduction of scenes with motion, many of whom compete most vigorously with one another in the open markets. It is a matter of considerable pride to the Society that such vigorous and sometimes bitter competitors in commercial life find it profitable to meet together under the impartial auspices provided by the technical sessions and the committee activities of the Society. The impartiality of these meeting grounds must never be questioned if the Society is to enjoy the support of all its members, and if it is to grow in accordance with its opportunities.

It is the purpose of this restatement to emphasize a fundamental policy of Society operation, which is directed toward the maintenance of such an unquestioned impartiality. Briefly, this policy is simply that the Society shall refrain altogether from participation in the comparative testing of competitive goods.

The obvious wisdom of such a procedure would scarcely seem to require a formal statement such as this. However, opportunities for transgression continually arise, particularly in the conduct of the normal affairs of the Engineering Committees of the Society. The development of suitable test methods, and, in many cases, the establishment of the manufacturing tolerances and performance levels which can be expected of good equipment are among the most important duties of these Committees. To develop new methods and limits, the full co-operation of industry is relied upon, including the opportunity to make extended tests on commercial equipments, with mutual confidence that the results of these tests will not be made the basis for competitive publicity involving the Society.

The Society, of course, encourages the use by industry of approved Society methods and tolerances in competitive commercial testing. Moreover, if a commercial interest wishes to publicize the fact that Society-approved methods were used to authenticate its claims, that, too, is encouraged. Authorization is never granted, however, for any implication of Society participation in, or validation of, the test results themselves.

Board of Governors

The first meeting of the Board of Governors in 1950 was held in New York, January 31, with Earl I. Sponable presiding. As is customary, the agenda was a heavy one and the meeting ran well into the late afternoon. The Board reviewed the Society's accomplishments for the previous twelve months and studied the details of all business operations involved in turning out the JOURNAL and test films, of engineering and non-technical committee work, as well as administration of Society membership matters. The resulting year-end fiscal picture was analyzed in detail and together with recommendations of the Officers, Headquarters Staff, and many committees, was used as a basis for planning work to be undertaken in the coming year.

William B. Lodge, whose term as a Governor expired in December, was reappointed for an additional year to fill the second half of a two-year term vacated when Fred T. Bowditch was elected to the office of Engineering Vice-President. As Vice-President in Charge of Engineering for Columbia Broadcasting System, Mr. Lodge brings the views and opinions of television engineers generally to deliberations of the Board.

Among the changes approved in the recent amendment to the Society's Constitution was the creation of two additional Governorships, increasing the number of Board members to twenty-four. There will now be twelve elected Governors, four from the Eastern time zone, four from the Central Zone and four from the Mountain and Pacific zones. After some consideration the Board ruled that it would decide at the April meeting whether the two new offices should be filled temporarily by appointment, or by the 1950 election.

Since the recently approved Constitutional Amendment is now in effect, the President's Committee on Revision of the Constitution and Bylaws has turned its attention toward drafting a proposed Amendment to the Bylaws. Changes which the Committee was asked to consider were intended to bring both documents more nearly into agreement and it was hoped that certain complex wording, redundant phraseology, and some outright conflicts would be resolved. Prior to the meeting, the first formal draft of the Committee's proposal was reviewed by the Board members who have now approved referring it to the voting membership for their consideration. This will involve publication in the March JOURNAL and discussion followed by a formal vote during the 67th Convention.

67th Semiannual Convention

On April 24, the 67th consecutive semiannual convention of the Society will get underway at the Drake Hotel in Chicago. Bill Kunzmann, Convention Vice-President, George W. Colburn, Central Section Chairman, and R. T. Van Niman, Chicago Vice-Chairman of the Papers Committee, report that advance arrangements are shaping up nicely and they plan to provide for both a full program and large attendance.

The five-day convention is now scheduled to include ten technical sessions, with papers on a variety of subjects ranging from projection arc lamps to production techniques for television studios. Members and their guests will start the ball rolling at 12:30, Monday, April 24, with a 'Get-Together' luncheon in the Gold Coast Room of the Drake Hotel. On Wednesday, Bill Kunzmann will, as usual, call time out from the official business of this, his 67th convention, for a midweek evening of fun and frolic. The 67th Banquet and Dance will follow a one-hour Cocktail Party, scheduled for 6:45 P.M. in the hotel's French Room.

Mrs. George W. Colburn, Convention Hostess, invites members to take their wives to Chicago and promises them a worth-while week because her committee is arranging a Ladies' Program that will be both interesting and entertaining.

Bill Kunzmann announces appointment of the following Convention Committee Chairmen:

Central Section and Local Arrangements, G. W. Colburn

Papers Committee

- Chairman, N. L. Simmons, Jr.
- Vice-Chmn., Chicago, R. T. Van Niman
- Vice-Chmn., Hollywood, L. D. Grignon
- Vice-Chmn., Montreal, H. S. Walker
- Vice-Chmn., New York, E. S. Seeley
- Vice-Chmn., Washington, J. E. Aiken

Publicity, Chairman, Harold Desfor
  Assisted by Leonard Bidwell and R. T. Van Niman

Registration and Information, E. R. Geib
  Assisted by C. E. Heppberger, J. L. Wassell, and C. L. Lootens

Luncheon and Banquet, Carrington H. Stone

Hotel Reservations and Transportation, Harold A. Witt

Membership and Subscription, Lee Jones
  Vice-Chairman, Central Section, A. H. Bolt

Ladies' Reception Committee Hostess, Mrs. G. W. Colburn

Public Address Equipment, Robert P. Burns
  Assisted by R. Hilton and R. Gray

Projection Program, 35-mm, I. F. Jacobsen
  Assisted by members Chicago Projectionists Local 110, I.A.T.S.E.

Projection Program, 16-mm, H. H. Wilson

The Papers Committee has sent Author's Forms to many members who expect to present technical papers. If you would also like to be on the program, don't fail to get your Author's Form from the member of the Papers Committee nearest you. His name and address are listed on p. 116 of the January JOURNAL.

Society Announcements

Membership Directory—1950

To be certain that your name is listed correctly in the Society's Membership Directory for 1950, return your envelope-questionnaire promptly.

Nominations—1950

All voting members are invited to recommend candidates for the ten vacancies on the Board of Governors which will occur on December 31, 1950. Refer to p. 113 of the January JOURNAL for the specific offices and governorships to be vacated, as well as for the names and addresses of Nominating Committee members.

Society Awards—1950

Candidates are considered each year for five formal Society awards. A concise listing of the awards and the qualifications of recipients appeared on p. 113 of the JOURNAL for January, while a detailed reference with the names of previous recipients appeared in the April, 1949, JOURNAL.

Test Film Catalog

A new catalog, listing all test films for both motion picture and television use produced by the Society and the Motion Picture Research Council, has just come off the press. Copies are available to all who use 16- or 35-mm projectors or sound equipment. Members are urged to make copies available to their own business organizations and also to friends and acquaintances who are concerned with the design and manufacture of film handling equipment or with the quality reproduction of picture and sound.

High-Speed Photography

The Society is pleased to announce that *High-Speed Photography, Volume* 2, a complete reprint of the articles on high-speed photography from the November, 1949, JOURNAL, is now available. This follows Volume 1, published as a supplement to the JOURNAL in March, 1949, and is of great value to all who use high-speed photographic methods of analysis.

Seventeen articles by noted authorities cover the field of equipment now available commercially and in addition describe a number of special cameras and associated control equipment developed for unusual needs. Of these seventeen, five are primarily "technique" papers that give new users of photo-analysis methods a good grounding in various specific applications with an idea of the broad capabilities of scientific photography.

Volume 1 (129 pp., $1.50) and Volume 2 (177 pp., $2.00) are companion reference works developed by the High-Speed Photography Committee under the chairmanship of John H. Waddell. They are the only publications of their kind and are therefore essential to the serious use of photography in government and industry research laboratories.

Journals Out of Stock

The Society's stock of JOURNAL issues for January, March, and July, 1949, has been exhausted as a result of an unexpected increase in demand and the Society's Headquarters is anxious to purchase a stock of each. Members or libraries having extra copies available are invited to send them in. The going price is 75c.

Engineering Committees

Theater Television and the FCC

Frequency allocation continues as a topic of timely interest to members who have been following the work of our Theater Television Committee. Most recent sign of activity in this direction is a Public Notice from the Federal Communications Commission, released on January 11, and announcing plans for a Hearing on Allocation and Rule Making in the near future. This is by way of reply to statements by the Society and four industry groups favoring allocation of frequencies for theater television filed with the Commission in August, 1949, and to 26 individual petitions for a Public Hearing filed subsequently.

The Commission in its January notice indicated that it desires "to obtain full information concerning all aspects of theater television; and to afford all interested persons an opportunity to participate in furnishing related information."

The Commission reports that the Hearing would be held upon the following ten issues:

(a) To determine whether the existing and proposed transmission requirements for theater television can be satisfied by existing and proposed common carrier wire facilities or by existing and proposed common carrier fixed station facilities operated in bands of frequencies now allocated to such stations.

(b) To determine the order of frequencies and the spectrum space required, if any, at each order of frequency which would be necessary to establish a theater television service.

(c) To obtain full information concerning existing or proposed methods or systems for exhibiting television programs on large screens in motion picture theaters or elsewhere.

(d) To obtain full information concerning existing or proposed methods or systems for transmitting or relaying television programs from the point of pickup to the exhibiting theater, by use of radio frequencies, coaxial cable, wire, or other means, including intra-city and inter-city transmission.

(e) To obtain full information concerning any technical data obtained in experimental operations conducted in the theater television field, or otherwise available.

(f) To obtain full information concerning any nontechnical data obtained in experimental operations conducted in the theater television field, or otherwise available, including public need or demand for the proposed service, public need or desires in theater television programs, approximate uses for the service, and commercial feasibility of the service.

(g) To obtain full information concerning plans or proposals looking toward the establishment of theater television on a commercial or noncommercial basis.

(h) To determine whether persons engaged in furnishing theater television services would be engaged as common carriers for hire in interstate communications by wire or radio, within the meaning of Section 3(h) of the Communications Act of 1934, as amended.

(i) To determine whether, if frequencies are to be allocated for the purpose of providing a theater television service, such service should be established on a common carrier or non-common carrier basis, and if on a non-common carrier basis, the conditions under which such service would be made available.

(j) In the light of the evidence adduced under the foregoing issues, to determine whether or not the public interest would be served by the issuance of a proposal for allocation of frequencies to a theater television service and by the promulgation of proposed rules and engineering standards governing such a service.

All who desire to appear before the Commission on this question of the allocation of frequencies for a nation-wide theater television service have been invited to do so and are asked by the Commission to indicate their intentions by February 27.

Society Recommendations

In recent years many members who served on engineering committees of the Society have felt the need of some new form of official Society endorsement, short of formal standardization, that could be given to those reports or other committee conclusions that appear inappropriate for standardization under normal American Standards Association procedure. The Board of Governors recognized the need for validating these reports and in 1949 approved the publication of *Society Recommendations*. The Board reasoned that since study of technical problems by a Society engineering committee represents a great many man-hours and usually develops information of real technical value, details of certain projects that did not quite qualify for standardization should not be put away to collect dust or be submerged in annual progress reports but be available as published documents. It is the purpose of these Recommendations to formalize tentative conclusions so that they will be available for later engineering or research work.

The Recommendations for 16- and 8-Mm Sprockets in this issue of the Journal mark the first appearance of this new type of Society technical document. Two-column format will, for the present at least, distinguish this and forthcoming Recommendations from the rest of the Journal. Following publication, they will be reprinted to fit the standards binder but will be on colored paper to set them apart from the familiar American Standards on Motion Pictures.

Reprints of the Sprocket Recommendations will be available sometime after March 15th and all whose names appear on the Standards Mailing List will receive order forms. Distribution is by no means restricted and all engineers who wish to have this document at hand for reference are urged to order promptly.

35-Mm Sound Heads

The theater equipment industry has long been plagued with serious projector and sound head interchangeability problems. The lack of formal standards for such important details as size and location of mounting holes or dimensions and speeds of projector drive gears forces each manufacturer to provide a complete series of adapter kits to permit matching his equipment to all other combinations of projectors, sound heads, bases, magazines, preview attachments, etc. Because the problem is such a complex one, any real standardization is many years away; but for the time being, the Film Projection Practice Committee, under the chairmanship of L. W. Davee has provided a measure of relief. They have assembled a combined reference file of the basic dimensions that affect interchangeability of 25 different types of 35-mm theater sound reproducers. Included in this "1949 Sound Head Survey" are:

Ballantyne	RSM-6 & RSM-8	RCA	MI-9001
Century	R2 & R6	RCA	MI-9030 Series, MI-9050 Series, MI-9060 Series, MI-9070 Series
Century	RC & R5		
International Projector	SH-1000 through SH-1006	Wenzel	WSH-3
Motiograph	SH-7500	Westrex	Master R-2
RCA	MI-1040 Series, MI-1050 Series	Westrex	Standard R-3, Advanced R-4

Copies have been sent to the manufacturers who participated in the survey and they are now made available for purchase at $10 for each set of eleven, 24 × 36 in. blueprints.

New ASA Correlating Committee Formed

A new Correlating Committee on Photography and Cinematography is being formed to supervise the work of Sectional Committees Z22 on Motion Pictures and Z38 on Photography of the American Standards Association. Believing this change would reduce the work load of Z38 projects as well as allow projects of both groups to flow more efficiently, the ASA suggested such a move several years ago.

Approval was delayed by concern of several Z22 members who felt that their own efficiency would be reduced through additional approval steps required. They were also concerned lest the word "cinematography" replacing "motion pictures" in the committee's title imply an undesirable limiting of the scope of projects they could undertake.

Agreement was reached, however, when every assurance was given that, basically, proposed standards on motion pictures would be handled as before.

The new Committee will have fifteen members. Two Society representatives and two from the Motion Picture Research Council will be appointed in February and will attend the first meeting, scheduled for late in March. Details of operation will be developed at that time and a report on the new organization will probably be presented at the Society's 67th Convention in Chicago during the last week in April.

Section Meetings

Atlantic Coast

The Atlantic Coast Section meets on February 15, 7:30 P.M. at the Reeves Sound Studios, 304 East 44th St., New York City. Sound recording and television engineers are certain to be interested in the synchronous one-quarter inch magnetic tape recorder that will be described and demonstrated by Drs. D. G. C. Hare and W. D. Fling of Fairchild Recording Equipment Corp. This equipment is being used regularly by at least one New York television station for double-system television film recording.

Central

The February meeting of the Central Section is scheduled for 7:30 P.M., February 17, in the 7th Floor Auditorium of the Western Society of Engineers, 84 E. Randolph St., Chicago. George W. Colburn, Section Chairman, reports that this will be a joint meeting with the Institute of Radio Engineers and the Chicago Audio and Acoustical group. There will be four technical papers, two on sound, one on television, and one on color. The first, "Some New Developments in the Field of Sound Reproduction," will be presented by Dr. Harry F. Olson, RCA Laboratories, Princeton, N.J., who will describe RCA's new highly directional microphone and its use in television and motion picture studios. The duo cone loudspeaker will also be described and a low cost, wide range recording and reproducing system will be demonstrated.

The second paper, "Development and Application of the Short 16-In. Metal Kinescope," will be presented by Mr. Lloyd E. Swedlund of RCA, Lancaster, Pa. In addition to reviewing the history behind the development and design of the 16GP4 picture tube, Mr. Swedlund will present practical information on its use and the use of several other new tubes.

Mr. Frank McIntosh of McIntosh Engineering Laboratory, Silver Springs, Md., will present a paper, "New Developments in Audio Amplifiers." This amplifier has been much discussed in audio engineering circles and is certain to capture the interest of sound engineers.

A representative of the duPont Research Laboratory at Parlin, N.J., will describe briefly the new Palymar Color Process.

Preceding the meeting, there will be a Speakers Dinner in the 5th Floor Dining Room of the Western Society of Engineers Building.

Pacific Coast

The Pacific Coast Section meeting for February is a double-header scheduled for the evening of February 14. One part is "Recent Problems and Developments in Magnetic Film Recording," to be presented by Robert Herr, Research Physicist of Minnesota Mining and Manufacturing Co. All motion picture and television engineers who have been concerned with magnetic sound recording are acquainted with Mr. Herr and are certain to be interested in his discussion of some of the problems and techniques in the use of 35-mm magnetic films for motion picture sound work. This field of recording is distinct from applications which use non-synchronous tape. Aging characteristics of the magnetic medium are particularly important where sound records are to be used after a period of storage

or where there is delay in shipment. The data which will be presented on the various effects will be of considerable benefit to studio sound engineers who are now converting from photographic recording.

The other part has: first, "A New Technique for Synchronizing Multiple Television Originations" by Harold Jury, Chief Television Engineer, Don Lee Broadcasting System; and second, "Progress Report on an Electronic Background Projection System," by Wayne Johnson, KFI-TV, Los Angeles. Use of the projected background captured the interest of television engineers many years ago as a means of saving production time and space in television studios. Mr. Johnson's talk will include descriptions of an electronic method of applying a moving or still photographic background to a television picture.

Book Reviews

16-Mm Sound Motion Pictures, by William H. Offenhauser, Jr.

Published (1949) by Interscience Publishers, Inc., 215 Fourth Ave., New York 3. 546 pp. + 15 pp. index + 19 pp. appendix + xii pp. 123 illus. 6 × 9 in. Price, $10.00.

16-Mm Sound Motion Pictures is described by the author as "a manual for the professional and the amateur." What makes it more than a manual, however, is the inclusion of a good deal of information derived from the practical experience of the author.

Most of the chapters are devoted to the technical aspects of 16-mm photography, sound recording, editing, processing, and projection. Not only are representative equipments described with the aid of many illustrations, but also the techniques and methods are discussed at great length. Methods of quality control of picture and sound, from the planning of a picture to the projection of its prints, are outlined. The problem of emulsion position and precautions to be taken in this regard throughout the steps of picture making are clearly described. There is a chapter on the history and growth of 16-mm film and its relation to other sizes.

The chapter on film processing and printing is especially good. There is a chapter on color film and the duplicating process. Film in television is treated from the technical standpoint. Throughout the book, how-to-do-it information is profuse, in some cases, down to the last detail. Measurements in the processes are carried through step by step, with the help of illustrative examples. This is very helpful and increases the value of the book.

Liberal reference is made throughout the text to motion picture dimensional standards and practices of the American Standards Association, and their importance in attaining professional results is stressed. An appendix contains standards of nomenclature and various useful charts and symbols.

The book is recommended to the many technicians working with 16-mm film. Each specialist not only will find it helpful in his particular area but also he will find that it enables him to broaden his technical knowledge in this rapidly expanding field.

Lloyd T. Goldsmith
Warner Bros. Pictures
Burbank, Calif.

The Recording and Reproduction of Sound, by Oliver Read

Published (1949) by Howard W. Sams & Co., Inc., Indianapolis 1. 358 pp. + 6 pp. index + x pp. 256 illus. Price, $5.00.

All those interested in the recording and reproduction of sound will discover in this book a wealth of information that will prove very useful, whether to them as hobbyists, operators of commercial equipment, or even as engineers. It describes the subject in clearly understood language, yet uses less mathematics in doing so than has been observed by this reviewer in any other similar book. The engineer, who is frequently a specialist in but one or two methods of sound recording or reproduction, should also welcome in this book an opportunity to review in considerable detail the other sound recording and reproducing techniques; and, as a result, his broadened knowledge of the subject should prove helpful in his own more limited field.

The chapter dealing with Columbia L.P. and RCA 45-rpm records is particularly timely and it points out the specifications and features of both systems as compared to the older 78-rpm records.

Of particular interest to all is the last chapter which covers proposed NAB Recording and Reproducing Standards and proposed American Standard Acoustical Terminology.

The appendix contains numerous useful tables, charts, and formulas for electronic service engineers as well as a tabulation of numerous disk recording troubles with their causes and cures. It also includes a glossary of many of the terms used primarily in the disk recording field.

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Meetings of Other Societies

Institute of Radio Engineers, National Convention, March 6–9, New York, N.Y.
Inter-Society Color Council, Annual Meeting, March 8, New York, N.Y.
Optical Society of America, Winter Meeting, March 9–11, New York, N.Y.
Armed Forces Communications Assn., Annual Meeting,
May 12, New York and Long Island City
May 13, Fort Monmouth, N.J.
Institute of Radio Engineers, Technical Conference, May 3–5, Dayton, Ohio
Acoustical Society of America, Spring Meeting, June 22–24, State College, Pa.

SMPTE Officers and Committees: The names of Society Officers and of Committee Chairmen and Members are published annually in the April issue of the Journal. Changes and corrections to these listings are published in the September Journal.

New Products

Further information concerning the material described below can be obtained by writing direct to the manufacturers. As in the case of technical papers, publication of these news items does not constitute endorsement of the manufacturer's statements nor of his products.

The new Huggins Ames Type A Mercury Arc Lamp has been designed to produce light intensities of 90,000 candles/sq cm. It is made by Huggins Laboratories, 778 Hamilton Ave., Menlo Park, Calif. Shown in the illustration are the lampholder with lamp extracted and, in the background, the a-c power supply. Light output is 65 lumens/watt; power consumption of the lamp is 2 kw (1.2 amp at 1750 v).

Arc dimensions are 2.85 cm (1.125 in.) by 1 mm (0.039 in.). Cooling is accomplished with ordinary tap water, $2^1/_2$ gpm being required. Alternatively, a closed-circuit distilled-water system can be used. Average life at rated maximum brilliance is 5 hr, and appreciably more at reduced voltages. In the standard model, 100 per cent intensity is reached at 4358 A, with an 80% peak at 5461 A, and a 73% peak at 4047 A, with a maximum radiation of 0.08 w per steradian per Angstrom. Intermediate areas average approximately 35%. Quartz accessories can be supplied for operation in the ultraviolet region. Direct-current, flash, and stroboscopic power supplies are reported as under development for special applications.

Uses reported are in interferometers, Schlieren optical systems, shadowgraphs, monochromators, in high-speed photography, and high-powered ultraviolet sources in the production of chemical, biochemical, and ionization changes in substances under study or processing.

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Project Engineer: Mechanical engineering graduate experienced in designing from specifications; optical instruments, precision cameras, mechanical servo, and gear or 3-bar computers, analytical work in stress and vibration. R. A. Barbera, 663 Ovington Ave., Brooklyn 9, N.Y.

TV and Motion Picture Engineer: 3 yr experience in motion picture engineering and research at Philips Physical Laboratories, Eindhoven; 6 yr as TV-Director, same firm; 3 yr as Director of Decca plant in Belgium. Desires asignment in any part U.S.A. Highest qualifications and references U.S. firms. Will visit New York and Chicago at the end of February. Write Fernand Beguin, c/o Mr. Marc Albanese, 416 Madison Ave., New York 17.

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By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased.

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Television Cutting Techniques

By RUDY BRETZ

Television Consultant and Producer; Head of Television Dept., Dramatic Workshop and Technical Inst., New York, N.Y.

Summary—**The techniques of motion picture cutting have in some measure found application in television cutting as well. Characteristics peculiar to the new field, however, have influenced the growth of new techniques. In this article the author outlines the basic principles of television cutting from the creative or production point of view. In a succeeding article he will discuss the equipment in use in television stations for the switching of picture signals.**

In motion pictures, a change from one scene to another is usually accomplished by a cut. The editor determines the exact point at which the change should occur, trims off the unnecessary portions from the end of the first scene and the beginning of the second, and then joins the two together with a splice. This process is called "cutting." To "cut" a film does not mean simply to reduce it in length by taking out unwanted portions. It is the whole process of putting a film together, choosing which shot shall follow which, determining the precise length of each and the exact frame on which each cut shall be made.

The cutter is the one who does the physical work of handling the film. The creative decisions are usually made by a "film editor," who may sometimes do his own cutting. Motion picture cutting is recognized as a vitally important aspect of the film art. It is a profession in itself. Some film makers have gone so far as to say that in the technique of cutting lies the entire process of creative film art.

In television, a change in the scene is made with an electric switch, not with the scissors and splicer. Strictly speaking, we should call it "switching" instead of cutting. But the word "cut" has come to mean an instantaneous change of scene; and, since that is what we produce by pushing buttons, it is still correct to call the process cutting. Both terms will be used hereafter: "cutting" when the creative aspects of the process are being considered, "switching" when the discussion is on the technical side.

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In end result, the process of cutting television is very similar to that of cutting motion pictures, but the method is entirely different. A film editor may take weeks to cut a show, deliberating over each decision. A television director has to do his job during the show itself. He must rely on fast thinking, quick reaction time, and thorough preparation. In some cases he relies on his script, or on his assistant, who follows the script. The sight of the television director excitedly calling shots ("Take Two! Take One!") has led some to think that shot calling is all there is to television directing. Some directors actually do forget to make full use of their cameras, because they are so occupied with just the problem of cutting.

In creative production a good director plans his cuts, just as he plans his camera shots: on paper. If he has had enough experience, he can visualize the effect of a cut, even between two shots which also exist only in his mind, or as thumbnail sketches on the margin of the script. He will not limit himself to what he has planned, however, once he has produced the shots with cameras and watched the effect of the cut on the master monitor. He may change the camera shots to improve the cut, or he may change the timing of the cut itself.

By far the greatest number of television shows, however, are produced with little or no rehearsal; and the cutting cannot be planned in advance. Even if camera shots are set in rehearsal, the cutting is very rarely the same on the final air show. This is because the timing of the cut or the choice of camera depends mainly on the performers. If they deviate from the rehearsed routine, or go through actions which have not been rehearsed at all, the director must be on his toes to adapt his cutting to their performance. This is called "off-the-cuff" shooting, "*ad lib*" cutting, or "winging" the show. The method of control-room operation makes a lot of difference in whether this kind of cutting can be successful.

METHODS OF CONTROL-ROOM PROCEDURE

1. The Switcher System

Under this system the director is in constant inter-phone connection with the cameramen. He is responsible for the placement and use of the cameras, and is considered in direct charge of the cameramen. He "calls his shots" to an engineer, whose function it is to punch the buttons which switch from camera to camera. This engineer is sometimes called the "switcher," sometimes the "technical director" (T.D.). This is the most common method in use today.

2. The Technical Director System

Under this system the director has no verbal contact with the cameramen. He will call shots to a technical director who punches the buttons as in the preceding case. The technical director under this system, however, is in charge of the cameramen and the use of the cameras, as well as all other studio facilities. He works with the cameramen as a team and with the director as co-worker. Sometimes the T.D. will take cuts himself especially if they have been established in rehearsal. Usually he will punch buttons only at the director's command. The director may talk to the studio during rehearsal over a loudspeaker, and he can talk to the floor manager over earphones. As far as I know this method is limited to the five NBC-owned stations across the country, to WABD in New York and WSB in Atlanta. It has been tried elsewhere and abandoned.

Proponents of this system see in it an analogy to the method of Hollywood production, in which each film has two directors, one of whom is the Director of Photography and is in charge of all technical aspects of the production, while the other carries the title of Director and is responsible for the dramatic action. Some directors, who have also worked under the switcher system, prefer this because it makes their work lighter. Relieved from having to think about cameras and cutting, they are able to do a better job with the directing of the actors.

One director, who has directed programs on many stations, says that working under the NBC system is like having a twin directing the program with you. During rehearsal much time can be saved. When in the course of rehearsal a stopping point is reached, the director can go out and fix the actors' errors and come back to the control room to find all the camera changes made and everything ready to go again. Of course this is predicated on the ability of the T.D. He must have almost as good a background as the director himself. He must be primarily a showman, not an engineer. Where this method is in use, however, the job of T.D. is always an engineering job. The T.D. must be in charge of the camera and control-room crew, and for this reason must be a superior engineer. Men who can fulfil all these requirements are rare, or cannot be found for the salaries that are offered.

The T.D. system breaks down when an inexperienced man is on the job, or when an *ad lib* show is attempted. I have watched a green director, a green T.D. and green cameramen attempt to use this

method, and the results were miserable. The director would give a camera order, and the T.D. would garble it a little in relaying it to the cameraman, since he had no clear idea of what was meant. Then the cameraman would do the wrong thing. "No! I didn't mean that!" the director would tell the T.D. "I meant so-and-so!" This was again relayed to the cameraman. This time the cameraman himself would make an error. When it was all finally straightened out and everyone knew what it was the director wanted, it would turn out to be something that couldn't be done anyway because of some technical factor which no one had anticipated.

During an *ad lib* show, camera and cutting instructions must be given very rapidly and acted upon immediately or action may be lost. Sudden instructions to the cameramen cannot originate in the director in these cases, since, by the time they are relayed through the T.D., the moment has passed. To be sure, the T.D. himself may wing the show; but he is acting then in the capacity of director, which very few T.D.'s are able to or would be allowed to do. A good T.D. could assist the director by keeping one step ahead of him. He could so engineer the cameras that the director would have a variety of shots to choose from in calling takes and one camera at least would always have a good shot, well framed, from the proper angle to show the action, and ready at the right time. There is some question, however, as to whether this could not be done just as well or more easily by the director himself. The general opinion is that for *ad lib* shows the T.D. system does not work. Since most television stations must do the *ad lib* type of production (and practically all remote pickups fall into this category), most stations have decided against this method.

3. The Director-Switching Method

In this method, the director not only talks to the cameramen but operates the switching system as well. Some of the smaller stations have adopted this method purely for reasons of economy, and because there was no local union jurisdiction over the job. Others have chosen it because they believe it to be the best method of control-room operation. The exact moment that a switch is made is very important, and a split second's delay can often mean the difference between a good and a bad cut. In baseball pickups, a bad cut is much worse than that: it is a lost play. A majority of the stations have adopted the director-switching system at least for baseball and other sports remotes. A few have carried the policy over into studio

operation. WCAU-TV and WPTZ in Philadelphia are good examples. Making a comparison with the T.D. system, they say at WPTZ, "It is easier to train a director to punch a few buttons than it is to teach an engineer showmanship."

This method of operation works out fairly well in small stations and on programs which are not too complicated. In the production of dramatic shows, however, it is advantageous to the director to be able to dispose of the burden of handling the dials and switches.

PRINCIPLES OF CUTTING

The principles of cutting that I shall outline here are the same that have governed film editing in all but the most esoteric types of films or film sequences. These are the techniques that achieve a "smooth cut" and assure a visual continuity. Good cutting, under this criterion, is unnoticeable. Two shots are joined in such a way that the audience is completely satisfied by the result and its attention can properly remain with the action, rather than being distracted by the method of production. Subject is more important than form in this type of production.

Basically, the responsibility of the television director is to satisfy the viewer. When something is going on and the director is making pictures of it, he must show it properly, or the viewer will be dissatisfied. He must show the viewer what he wants to see. Forty years of an ever-improving motion picture art has educated him to expect a lot. He wants close-ups on essential action and he wants them quickly, just as he is used to getting them in the films. He wants to look around and know where he is and he expects good orientation. Above all, he doesn't want to miss anything that happens and he doesn't want to be confused.

The director must show the viewer what he wants to see, when he wants to see it, and cause him no confusion in the process. If the television director can achieve even so much as this, he will be a good director. Fancy angles, subjective camera and montage cutting also have their place, but they can never substitute for the basic requirements.

Showing the viewer what he wants to see might better be classified under camera handling than under cutting. But showing it to him when he wants to see it is definitely a principle of cutting. The timing of the cut is perhaps the most important single thing about it, and the

one thing that is most likely to be a little off in television. Film editing procedures take account of the timing factor and usually include a "rough cut" stage where all the scenes are overlong. When the film is projected and studied in this condition, cuts can be more exactly timed. In television such a procedure is impossible. A long shot and a medium shot which are to be cut together exist side by side on two monitors. A switch between them is instantaneous and irrevocable.

Within a sequence of shots taking place in one scene, the actual length of an action cannot be changed. An actor crosses the room, and we cut to a close-up when he reaches the other side. In film editing there is a possibility of shortening the actual time of the cross. If the actor walks out of the frame on the first shot and into the frame on the second, the entire intervening time can be eliminated. This is known as "creating filmic time." In television we can condense time in this way only between sequences or by special devices, but not in the regular run of shooting. We are limited to actual time, since television is basically an art of actuality. The choice, by the director, of the best segment of this actuality, at the best time, is the process of artistic selection, which is a good part of what might be called the creative art of television.

Dependence on actual time, however, simplifies television cutting as compared to cutting film; there is no need to worry about matching of action. In film shooting, it is always a constant worry to be sure that the action is the same when you shoot a close-up as it was when you shot the medium-shot just before. If an actor sits down, he must do it at the same speed each time, hold the chair with the same hand, cross his legs in the same direction, etc., or joining the two pieces of film will be a great problem. Then, in film cutting, even when you have two shots with identical action in them, there is the problem of cutting between them, so that the action, which begins in one shot and ends in the other, will be smooth and continuous. There must not be any overlapping or anything missing. This also we are spared in television.

Cutting on Action

The principle of cutting on action is just as important in television as it is in films. There is nothing that will so disguise the fact that a cut has been made as a strong and positive action to carry across

from one shot to the next. The cut should be made during the action itself, not just before it, and not after it. As a director you must watch your monitors very closely, have the second camera ready, call the first half of your order, "Take . . .," and just at the moment of the move, call the camera number. If it is a short movement, like a dancer's leap, for instance, and there is any delay at all, the cut will come after the leap is over.

It is very important for the switcher or technical director who punches buttons to know ahead of time which camera is to be taken next. His reaction time is faster then. He has only to punch the button. He doesn't have to decide first which button to punch. KLAC-TV in Hollywood has established a rule requiring directors to call the camera number first, before they call the take. If they say, "Two. Take Two," it gives the technical director time to get ready, and a well-timed cut results. In spontaneous cutting, however, it is not always possible to anticipate sufficiently ahead of time. Many of the directors' orders at this studio sound more like "Twotaketwo," which is no great advantage, and just gives the director more to say.

The director's best method, I believe, is to give a "ready" cue whenever possible. This is appreciated also by the cameraman who is not so likely to be caught changing lenses or adjusting focus at the moment of the cut. "Ready Two" can be said almost automatically while you are watching the action on camera Two. Where the cut must be precise, a further "Take . . ." will keep the technical director poised. Then the number can be thrown very quickly, accompanied if desired by a hand signal, and the reaction is almost as fast as though the director himself pushed the button.

The moment of action is such a natural place to cut that it is possible to violate the other principles of good cutting and get away with it, as long as the cut is made on action. For instance, one principle, which I shall describe later, is concerned with keeping left and right straight in the viewer's mind. Whoever is looking or moving left in one shot should be looking or moving left in the next, if the action is to match at all. However, Don Hallman at WXYZ-TV covers wrestling with two cameras, which are on opposite sides of the ring. The purpose of this setup is that one camera can see what is hidden from the other. He has great problems in cutting, however. Whenever he switches cameras, the contestants change places on the screen. Hallman's method is to wait for a positive action before making his

switch. A definite action (and there are many such movements in wrestling) will leave no doubt or confusion in the mind of the audience as to which person is which.

Cutting on action is possible, however, only if the attention of the audience is definitely centered on the action through which you intend to bridge the two shots. If you start with a long shot which includes several actions, the audience is as likely to be watching one as another. If the shot, let us say, shows four football players warming up before a game by kicking punts, and the director should wish to cut to a close-up of one of them, he cannot do this on the action of the kick. There is a three-to-one chance that the viewer may not be watching the same player that the director is looking at. If the viewer's attention happens to be on the wrong player, the new shot will suddenly be upon him in the midst of an action. It would be best in this case to cut before the kick, so that the complete action would be included in the close-up shot, just as one would do in cutting to another scene, when matching of action is unnecessary.

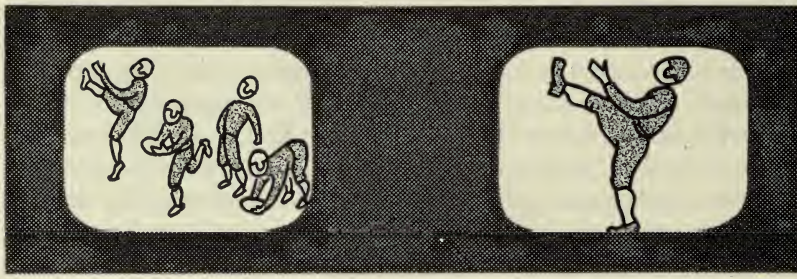

Figure 1

Cutting on Reaction

One of the most powerful motivations for a cut is to have someone in the picture look outside the frame. Immediately the audience wants to see what he is looking at. A shot of another subject—anything under the sun—is accepted, at least momentarily, by the eager viewer. The viewer has been shown what he wants to see. More than that, the director has contrived, by the device of having someone look, to make the viewer *want* to see the thing the director is going

to show him next. He can cut to almost anything at all and make a good cut. For a joke, he can even put in something ridiculous. If the shot is entirely impossible and incongruous, the viewer will laugh at himself for having accepted it, but only after a smooth and natural cut has been foisted on him.

This same general principle applies in the case of an actor pointing a camera or a gun. The audience wants to see what the actor is aiming at.

Such a device can be used to motivate a cut to a very big close-up, from a medium- or long-shot. Usually it is best not to make the change of shot too extreme. Long-shot to medium-shot, medium-shot to close-up, close-up to big close-up is the normal progression. But if a person picks up a picture or a letter or obviously concentrates his attention on a very small portion of the scene in front of him, a cut to that small area is perfectly motivated.

Cutting is often motivated when the audience wants to see someone's reaction to what has just been said or done. In the audience participation show, a contestant is blindfolded and put through some silly stunt. A shot of his wife's reaction to his asininity is completely motivated (provided she is reacting at all). In the dramatic show, when two people are in conversation, it is often desirable to cut to a close-up of the person who is not talking, in order to watch his reaction to what is being said. Standard procedure under other circumstances, when covering a conversation, is to show the person who is talking, at all times, and to cut back and forth on every speech. You have to show the viewer what he wants to see, and he is interested primarily in the source of sound. Noises off screen, the opening of a door, or a voice, will make the audience want to see where the sound is coming from.

The Cut-in or Intercut Shot

Sometimes during the course of an event or performance it may enrich the show to cut away from the event and interpose a shot of something else. A spectator reacting to a sports event, or not reacting, as the case may be, is a good example. The newsreels frequently intercut a close-up of screaming fans just after a good play or show a long-shot of the stands if the preceding action has not been too exciting. But in films this serves a practical purpose, which does not hold true in television.

An intercut shot in a film can be used to separate two shots that do not match and cannot be cut together. A smooth continuity results. Moreover, the film audience does not mind being taken away momentarily from the primary action, because it knows that the film editor has included the rest of the scene in the reel, and that it is not going to miss anything. The television viewer, on the other hand, feels no such certainty. He is afraid, while he is watching the frenzied fans jumping in the stands, that he is missing something going on down on the field. The same is true of audience participation shows, comedy shows, variety shows and many other kinds of spontaneous programs. If intercut shots are to be used at all, they must be used at a time when nothing of importance is likely to happen elsewhere, or they will not be what the viewer wants to see.

A dramatic show is much more akin to a film in this regard. The thing is built and presented as a whole. It is not segments of reality, and the audience has no fear of missing anything.

All of the cinematic techniques are applicable to television dramatic shows, if they can be physically accomplished at all. Intercutting of extraneous shots for purposes of contrast, irony, flashback, etc., can be accomplished as well in television as in the film medium. These techniques are analyzed in such books as Rudolf Arnheim's *Film*, Raymond Spottiswoode's *A Grammar of the Film* and Ernest Lindgren's *The Art of the Film.*

Length of Shot

Among people who don't know too much about the art of cutting, there is prevalent a misapprehension that a lot of cutting increases the tempo of a production. This is carried so far that statements like this have been heard: "There should be a cut at least every 20 seconds in order to keep audience interest." This is by no means always true. A shot should be as long as the proverbial piece of string. Tempo is not controlled only by the rate of cutting, except perhaps in newsreels or documentary films. For instance, in the newsreels or in the "March of Time," films which are built from a series of more or less disconnected shots, scenes of three or four seconds in length are standard. A shot containing action should be continued as long as necessary to complete the action, or cut as short as possible, one might rather say, without *losing* any of the action. "The True Glory," a war film made from thousands of stock shots taken by a great number of Signal Corps cameramen, was cut to a very rapid

pace. The shots were, straight through the film, less than two seconds in length. This resulted in a picture which was very hard to watch.

Cutting, in this type of film, does control tempo, because it controls the speed at which the film progresses from subject to subject. Television production, however, is not like this at all. Cutting, in television, is usually not from one subject to another, but from long-shot to medium-shot to close-up, etc., all on the same subject. The speed at which the actors in the play progress from action to action is what determines tempo. All the frantic cutting in the world can't speed up the show.

I remember once, as a young director, being given a sports interview show to direct. The master of ceremonies and the interviewee sat together on a sofa and talked. Here was my great opportunity to do a real production. I dollied the cameras in and out. I cut from one angle to another: big close-ups, high two-shots, timing each cut accurately with the phrasing of the conversation, building up what I thought must be a terrific pace. But I succeeded only in sweating up the camera crew and making it hard for the audience to relax and pay attention to the interview. The show remained nothing more than two people sitting on a sofa and talking.

What is the absolute minimum length of shot? is a question that is sometimes asked. Four frames of film are enough to give the film audience a glimpse of a subject; there are shots of this length in some of the montage sequences in Hollywood films. It is amazing how quickly the eye can take in a picture. Back in the Keystone Comedy days they found they could get a better laugh if they cut in close-ups of action. If the action was only a pie hitting a face, or a quick change of expression on a comedian's countenance, it was included in a few frames of film, and there was no need to run the shot even as long as one second to show what had happened.

Fast cutting is very rarely desirable in television, and hardly ever possible. For one thing, you run out of shots too fast. You have only two or three cameras, and you have to allow time between takes for the cameramen to line up new shots or you will be repeating yourself.

Furthermore, television doesn't call for the pace of the motion picture. The two media are different in this respect. Since the audience is watching reality in the case of television, it is content to let events take their own natural time. It is hard to imagine a group of people sitting through a two and a half hour film of a football game in the

way that they will watch a full-game telecast. As movie-goers, they are used to a condensation of time and a tempo of production which is purely filmic.

Cutting vs. Camera Movement

Since the film is a construction made out of shots spliced together, it is natural that the cut would be accepted as the normal thing. Television, on the other hand, is an electrical pickup of reality. The television camera makes pictures continuously, as long as it is turned on and the beam control is up. Theoretically, the long continuous shot is more natural to the television medium. Furthermore, a television show is much less a construction than it is reality itself. The television viewer feels toward the receiver as though it were a kind of window through which he can see distant events. The more real this view, the stronger his feeling. These theoretical considerations seem to indicate that cutting is something to be avoided in television.

Camera movement is, of course, the alternative. Instead of cutting to a closer shot, why not dolly in? Is it not better to use a Zoomar lens on a baseball game than to cut from camera to camera? By and large, this is true. Tony Bunzman, who directed at NBC before the war, did some very fine dramatic shows with only one camera. There are times, however, when the advantage of a cut over camera movement is very great. Several such advantages can be listed:

1. One practical consideration is time. It takes time to dolly in to a close-up, and back again. The action must slow down and wait for the camera. It is much better to cut to a close-up and cut away from it again in a matter of seconds, and get along with the show.

2. Rehearsal time is also involved. A dramatic show can be planned with a great deal of actor and camera movement, or it can be done by cutting between a series of static shots. A lot more rehearsal time is needed to produce a show with camera movement. The movement, the positions of the actors and the co-ordination of the cameras, all have to be carefully worked out and well rehearsed if they are to work at all. Simple cutting from one shot to another can be worked out in much less time.

3. Reaction shots, also, often cannot be made by panning or dollying the camera. When the viewer sees someone look at something, he wants to see immediately what the actor is looking at. The viewer is seldom content to wait through a long pan shot across unimportant background to see it.

4. Another consideration is the dramatic value of the cut itself. The sudden appearance of a new picture on the screen can be put to good use sometimes, entirely for its shock value. This is particularly possible if cuts have been used sparingly in the sequence just before. A sudden dramatic moment can be enhanced by sharp cuts. A cut is useful for punctuation, something that is more difficult to accomplish with camera movement.

Matching the Center of Interest

When a cut is made, the eye must quickly adjust itself to a new composition. The easier the readjustment, the less noticeable and the smoother is the cut. One factor which determines this smoothness is the relative position in the frame of the center of interest in each case. In the first shot in Fig. 2 the center of interest is the

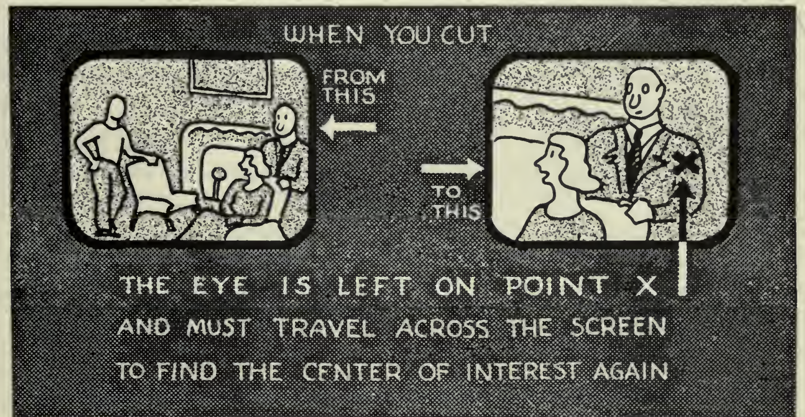

Figure 2

woman talking, in the lower right corner of the screen. If a cut is made to a close-up of the same subject, but composed so that the woman is then to the left of the screen, a readjustment of the eye is necessary. The eye remains focused on the lower right corner after the cut, with nothing particular to look at. It must find the center of interest again in its new position on the screen.

This is really a minor point in television, since there are usually so many other, more important things unaccomplished. Where greater perfection is desired, however, it is something to consider. An ex-

ample is in the pickup of sports. The smoothest possible cutting is necessary in covering sports because even a momentary confusion is enough to cause the viewer to lose track of a play, particularly in a fast game. It is about all you can hope for if each camera merely centers on the action. If each camera centers the ball, at the moment of the cut the ball will remain in the same place on the screen.

Cutting to the Audio

Sometimes, when all else fails, the phrasing of sounds will provide a natural place to cut. For instance, all else being equal, it is smoother to cut at the end of a sentence than in the middle of one. The phrasing of music forms a very compelling pattern for cutting, especially when the music plays an important role. The music is reinforced if the visual change follows the changes of tone color, chorus and verse. Clark Jones, one of the best directors in this field, is known for his accurate cutting in musical shows. His shots may be eight bars, four bars, sometimes only two bars in length, depending on the change in tone color of the music, and the cut is always made precisely on the beat, showing the new musician just as he begins to play. When tone-color changes every two bars, so do the cameras; when a vocalist sings 32 bars without a break, the camera rests quietly with the subject.

What Not to Do in Cutting

To the tyro director who has had little experience in the film or television media, I would direct the following words of caution:

1. Don't cut too much. You are likely to make the show harder to watch, or to irritate your audience. If you have time to work it out, camera movement or actor movement is smoother. Use the cut for dramatic punctuation or to get a shot on the air quickly. Don't go crazy with "brilliant" cutting unless you know what you are doing.

2. Don't cut blindly. Some directors seem to close their eyes and say, "Take Two." They are afraid to take their eyes off the master monitor. Keep looking back and forth, try to watch all the monitors at once. And look at the camera monitor before you call the take. You'll get fewer lens changes and out-of-focus shots on the air, if you do.

3. Don't cut from one shot to another one just like it. A cut from a two-shot to a two-shot adds nothing. To be sure, the second one is

from a different angle, but does it show the audience anything more?

Never let two cameras give you the same shot. Be sure that one of them changes lenses or repositions, otherwise it might as well not be out there. Sometimes a director gets stuck and has to cut between two identical shots, bad as such a cut may be. He may find, for example, that he has to release the camera which is on the air for some sudden need. He must cut to another camera. His only possibility is an identical shot on another camera, and he hasn't time to change it to something different. The viewer doesn't hear his excuses, however; all he sees is a bad cut.

The worst example I can remember of cutting between similar shots occurred on a musical program. In this case it was close-ups of a singer. There were three cameras: one presenting a full face of the girl, one a left profile the same size, and the third a right profile, also the same size. During the song the director changed shots often. There might have been a small reason for this because of the variety obtained by the change of angle, except that the performer was too smart for them. She was on to television. As soon as the camera changed, she spotted the red lights out of the corner of her eye and turned to face the new camera. Thus wherever the director shot from, he always got a full-face close-up. The singer continued to chase the cameras around for the rest of the number.

4. Don't cut to an extremely different angle. What constitutes too great a change in angle is hard to define. The main thing is to be sure that the subject is immediately recognizable and doesn't look like something else in the new shot. A shot from an angle that is so far different that an altogether different background is seen behind the subject will cause confusion. Sometimes a change of angle will make a great difference in the lighting. What is contrasty side-light from one angle may be flat front-light from another. The difference may be so great as to make the subject unrecognizable, at least for a moment. I have seen a profile shot of a news commentator cut in suddenly after we had been watching a full-face shot, with the result that the profile shot looked momentarily like someone else sitting across the room watching. The audience has no way of knowing that the new shot is taken from a different camera angle until they have seen the shot and comprehended it. The natural assumption is that it is taken from the same place, but looking in a different direction, just as an observer on the scene would turn and take in another view.

The problem of camera placement in the pickup of baseball and other sporting events is directly tied in with this. When an action takes place *between* two cameras, so that they see the subject from opposite sides, the direction of the action will be completely reversed when a cut is made. Nothing can be so utterly confusing. It is usually best to keep at least the main two or three cameras as close together as possible on most sports pickups.

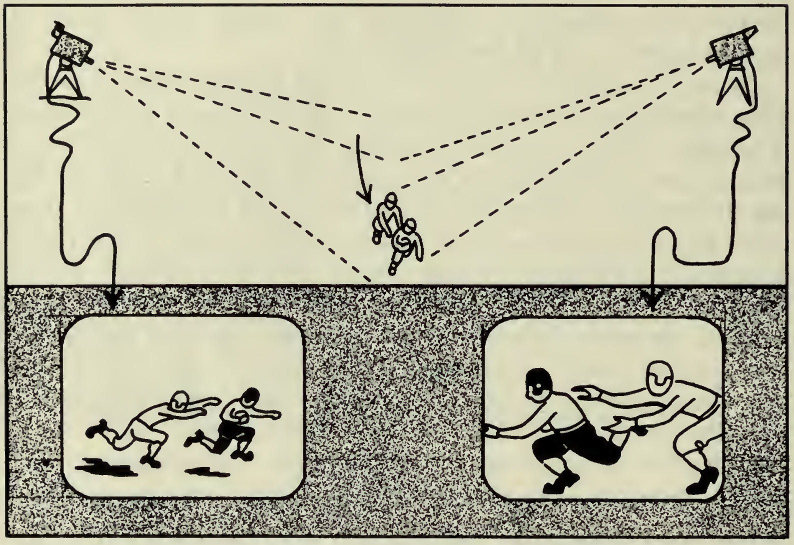

Figure 3

5. Don't cut on a pan. Don't cut from a camera that is panning to one that is static, or from a static camera to one that is panning. Try it once and you will see what I mean; it just can't be done. You *can* cut from pan to pan very nicely, providing they are both going in the same direction and at the same speed. When two cameras are following the same action, for example, the cut is usually quite smooth. At a football game, if both cameras center the ball as they follow an end run, it is perfectly possible to cut from medium-shot to close-up without the slightest confusion, since both cameras will be panning, and in the same direction.

6. Don't spoil exits. As far as the audience is concerned, once an actor has left the frame of the picture, he has made his exit. Don't rediscover him and exit him again in the background of the next shot.

ALTERNATIVES TO THE CUT

The Dissolve

The dissolve, lap dissolve, or cross-fade is the method of transition in which the first picture becomes steadily weaker while the second becomes stronger on the screen. It is really a fade-out simultaneous with a fade-in. If you stop the process at the mid-point you have a superimposure: each picture at half strength.

In films, the dissolve has been used with a certain connotation. By unwritten agreement, all film makers found it best to reserve the dissolve for a particular purpose. (The expense of having dissolves made assisted toward this end.) The meaning of a dissolve in films is transition through space and time. You dissolve between sequences: to a later time or to another place, or both. Dissolves within a sequence where no lapse of time is intended are rarely used in films, unless it may be by an amateur, fascinated with the dissolve mechanism on his camera, who dissolves between the long-shot of a garden and the close-up of a flower.

In television, unfortunately, a dissolve is no harder to do than a cut, and costs no more. Instead of taking another day to accomplish it, as we do in films (taking out the proper negatives, sending them out for opticals, then splicing back the dupe negatives into the reel), in television you simply turn a dial, or move a handle, as the case may be. With the Dumont equipment, as I shall explain in a later chapter, you punch the same button you ordinarily punch for a cut, and a dissolve is automatically effected. It is much too easy.

The result is a very free use of dissolves, often in places where a cut is really preferable. Dissolving within a sequence is often done on television, particularly in musical or variety shows. In such productions the director usually feels less confined to the motion picture tradition than he does when he is producing a dramatic show. The television dramatic show seems to follow the motion picture technique as closely as possible. The result is that in television we have a new connotation (or a loss of any connotation at all) for the dissolve.

Don't go dissolve-happy. Don't use a dissolve when a cut would be better. Don't use a dissolve when camera movement would be better.

The Fade-out and Fade-in

The motion picture connotation of the fade-out has been retained in television. The fade-out is sometimes called the "dissolve to

black" in television, because of the electronic means of effecting it with the dissolve control. It has a connotation of finality; it indicates an end to something. It may be used in place of a dissolve to link sequences together, where there is a greater change in time or place than is usually indicated by a dissolve. A dissolve retains continuity; a fade-out–fade-in breaks the sequence. It is not good, for instance, to fade in and fade out a series of titles, since the audience will think with each fade-out that they have seen the last of the series. Similarly, a play divided into a number of short scenes with fades between, will lack the unity it might have had if other devices were used.

The most dangerous aspect of using fade-outs in television is that the length of blank screen between fade-out and fade-in may be too long. Audience interest drops very rapidly when there is nothing on the screen. There may be exceptions to this rule: certainly when sound or music carries through, the wait is not so bad. However, the timing of the fade-out, the blank screen, and the fade-in should always be carefully planned and rehearsed. The shortest possible blank screen is particularly important when the fade-out comes at the end of a program or spot announcement. Every second's delay in bringing up the next picture means an increasing loss of audience. Dial turning on television is a much greater problem than radio ever had to contend with. Directors and technical directors have sometimes failed to look past the conclusion of one program and plan the initiation of the next. They wait until the final fade-out, heave a big sigh and then start hunting frantically through their schedule and routine sheets for the next move, while the screen remains patiently blank. This problem became so acute during the early months of operation at WPIX that we had to enforce a rule against any fade-outs at all. All transitions were to be made by dissolves.

There are ways of doing fade-outs in a program other than by simply turning down the gain, or dissolving to black. Fade-outs can be done with the lights on stage: the old familiar black-out. This is easier if the number happens to be lighted by one spot light, which is all that needs to be cut. The light can be moved off the subject, or the subject can move out of the beam of the light. If the motivation is very carefully planned, the camera can be panned off into a dark area, or dollied behind a dark object. This device was used by Olivier in "Hamlet." Another variation on this is to have an actor walk directly into the camera until he blocks out all the light. Which-

ever of these devices is used to effect the fade, it is usually good to use the same thing in reverse for the fade-in of the following scene.

An unusual use of the fade-out–fade-in was developed by Bert Gold at WICU when that station had only one studio camera. In order to change lenses, or to go from one stage to the next, the picture had to be quickly faded, the change made, and the picture faded in again. This procedure called for close co-ordination with the cameraman, but was a good adaptation to the situation. Ideally, assuming complete freedom of camera movement and an expert cameraman, it should be possible to cover everything with one lens (say a 90-mm) and keep the camera on continuously. The need to fade the camera out and avoid showing lens changes or portions of the studio beyond the actual sets is an inheritance from the production techniques of other media. In television we don't have to shun the backstage view, except when illusion and mood would be broken. The more reality, the more immediacy, the better the television in most cases.

Other Transitional Devices

1. The white fade. To the best of my knowledge this was first tried by Carl Beier and Bernie Brink at CBS-TV in 1941. It consists in fading out to white instead of to black. Naturally when it was first discovered, everyone went white-fade-happy; and for a while it was used more than anything else, at least by the directors at CBS. NBC and Dumont, who were also on the air at that time, did not seem to think it was that good.

Since the screen was constantly alight, it had less of a feeling of finality about it than a fade to black. The first time one saw it, however, one tended to feel that something had gone wrong and washed out the picture. We found good use for it between a series of titles (black letters on a white ground) so that only one camera and easel were necessary. It was a "fade white, pull the card, fade back in" routine. I haven't seen it used in recent years.

2. The de-focus transition. This requires a little co-ordination with the cameraman. Ready the next camera you are going to use by having the cameraman put it out of focus. Then at the right moment, crank the first camera out of focus, cut or dissolve, and bring the second picture up sharp. It requires a series of cues such as this, "Ready Two out-of-focus. One, de-focus. Dissolve to Two. Into focus, Two." It is assumed that the cameraman on camera One will

re-focus his camera again without being told, as soon as the effect is over. This device is particularly useful where a character in the play passes out or falls asleep just before the transition. The de-focus effect may also be combined with the fade-out for a greater transition through space or time. De-focus the camera, fade to black, then fade in to the next camera and focus up.

3. Visual confusion or interference. Almost anything which fuzzes up or confuses the picture can be used very nicely as an alternative to the dissolve. It is best, of course, if the first appearance of the effect is motivated in some way. Whatever is at hand will do: people walking in front of the camera, fire, smoke, water, etc., in front of the lens. Distortion glass or crinkled cellophane might be used in front of the lens, but these special transitions are rarely utilized because they take time to rehearse and execute properly. Remember that the transition device may arise directly from the special effects within the show. Anything which confuses the picture will find its use somewhere as a transitional effect.

4. Fade-cut and cut-fade. These are additional combinations of the foregoing transitions, which have been used on television and should be included in this listing. It is sometimes desirable to fade out one scene slowly, and then jump right into another scene, using the shock value of the cut. Or a cut to black is sometimes indicated, where you want a sudden ending to a scene, followed by a fade-in to the next. A rather particular case of this can be taken from Ted Mill's "Garroway at Large" show. At the end of his program the casual Garroway picked up a camera cable that was lying across the studio floor and explained that it was the coaxial cable carrying the program across the country. "It's about time to end the program now," he said glancing at his watch and picking up a small hatchet. "Now this might hurt a little," he said. He brought the hatchet down and the picture went black. Then came a fade-in on closing titles. In a moment, however, Garroway was back with his closing gag, holding the cable with a big bandage around it: "This program comes to you from Chicago, where we have very good connections."

5. The wipe. This is a cinematic technique in which the new picture starts as a small area and grows until it covers the entire screen. Filmic wipes can be made in a great variety of patterns, and new ones can easily be devised to suit special purposes. The simplest is the plain horizontal wipe, which is the only one that has been done elec-

tronically in television. Several types of simple wipes can be done optically by shutters and masks in front of the camera. These will be discussed under special effects in another chapter in this book. A wipe between titles, for instance, is not to be confused with a pull-off or slide-through, which is a bodily movement of the title in front of the camera. In the true wipe, two cameras are used (or two stages of an effects machine) and everything is stationary. The only thing that moves on the screen is the line of demarcation between the two pictures as the area of one grows larger and the other smaller.

No standard connotation was ever found for the wipe in motion pictures. It is very rarely used in dramatic films, finding its greatest value as a decorative device in industrial films, film commercials and the like, which depend on surface devices for their visual interest.

Methods of doing an electronic wipe have been in the design stage for years. They were first put into regular operation by NBC in 1949. The first use of the electronic wipe was to produce a split screen: with two ends of a telephone conversation shown at once. What was even more remarkable, an interviewer in New York was shown on the same screen as an interviewee in Washington. This will receive more complete treatment under electronic special effects in another chapter. All the switching systems at NBC-owned stations (their own design) now are equipped with a dial control for making a horizontal wipe. A wipe is sometimes used to lead into a split-screen effect. A man starts a telephone conversation. On the opposite side of the screen a wipe begins, then proceeds far enough to reveal the person at the other end of the line. When the call is over, the second picture wipes back out again.

(*A chapter on* Switching *is scheduled for next month.*)

Spontaneous Ignition of Decomposing Cellulose Nitrate Film

By JAMES W. CUMMINGS

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Summary—Cellulose nitrate motion picture film in the advanced stages of decomposition is liable to ignite spontaneously. The danger of such ignition is reduced by inspecting stored film stocks and removing and destroying all decomposing film.

During the abnormally hot summer of 1949, numerous fires involving cellulose nitrate motion picture films were reported in New York City and adjacent areas. These fires occurred in processing and reclamation plants and in standard film storage facilities. Losses resulting from these fires, other than those of real property, were severe, for the majority of the films destroyed were original negatives and master copies, some dating back to the "silent era." Due to the fact that these fires occurred either after working hours or on week ends, no casualties to personnel resulted, although some firemen were treated for smoke inhalation.

National Archives and Bureau of Standards engineers who investigated the fires could find no evidence that they were due to the negligence of personnel or the careless use of cigarettes or matches, but rather they appeared to have originated in the spontaneous ignition of deteriorated nitrate film. The summer of 1949 was one of the hottest recorded in the New York area, with the temperature reaching a maximum of 98 F. The mean high temperature for the months of June and July, 1949, was 83.1 F, as compared to a normal for the period of 79.3 F. The rainfall for the entire month of June was only 0.16 in. in contrast to the normal rainfall of 3.33 in. for the same period. The lack of rainfall and the unusually high temperatures of the period seemed to create ideal conditions for the development of spontaneous ignition in film stores.

A Contribution: Submitted February 9, 1950.

Prior to the investigation of these fires it was generally believed that nitrate film did not ignite spontaneously at temperatures likely to be encountered in a normal film vault. At the request of the National Archives, the Fire Protection Section of the National Bureau of Standards instituted an investigation to determine the possibility of spontaneous ignition as an inherent hazard in decomposing nitrate film. Samples in various stages of decomposition were supplied by the National Archives for the purpose of simulating conditions which may have prevailed at the fire locations. These samples were stored in a special chamber, the temperature of which was controlled and re-

Fig. 1. Container in which reel of film was placed, showing thermocouple wires.

corded. The films were packed in individual cans with each wrapped in mineral wool to retain the heat of the exothermic decomposition reaction. The ambient temperature in the chamber was initially 95 F and, at intervals, was increased by small increments. After 17 days of this treatment one 1,000-ft reel of film, initially in an advanced stage of deterioration, ignited; the ambient temperature in the chamber at the time was 106 F. Subsequently, with the ambient temperature at 120 F, another roll of film ignited.

Tests made by the National Bureau of Standards have not yet been completed, but so far, some important conclusions can be drawn. Self-ignition temperature, which is dependent upon a number of factors, was not the same for any two samples. The lowest temperature

leading to ignition was 106 F. Because the number of samples investigated was small, it is doubtful whether this is the lowest temperature at which a reel of film can self-ignite. One reassuring aspect of the results of the tests to date is that no film in good condition has self-ignited.

Fig. 2. Reel of film which had spontaneously ignited during a test at the National Bureau of Standards.

DANGER NEXT SUMMER

At the moment, no one can predict what the weather conditions will be during the coming summer and it is quite possible that other regions may be confronted with abnormally high temperatures such as prevailed in the Atlantic Coastal Region during last year. This possibility offers the chance that there will be a recurrence of regrettable film fires. The hazard should not be underestimated for, even with abundant water supplies, cellulose nitrate fires are difficult to combat. Nitrate base film contains oxygen in chemical combination and does not need additional oxygen to sustain combustion. Furthermore, the fumes given off by its combustion are highly toxic and seriously hamper the fire fighters. They contain oxides of nitrogen which, if

inhaled, can be fatal. Shortage of municipal water supplies in many areas presents an acute control problem definitely requiring the constant maintenance of every safeguard.

METHODS OF FIRE PREVENTION

The results obtained in the Bureau of Standards tests indicate that good film does not self-ignite at ordinary storage temperatures. Therefore, the logical approach is to remove from storage all film showing signs of deterioration. Such film can readily be found by regu-

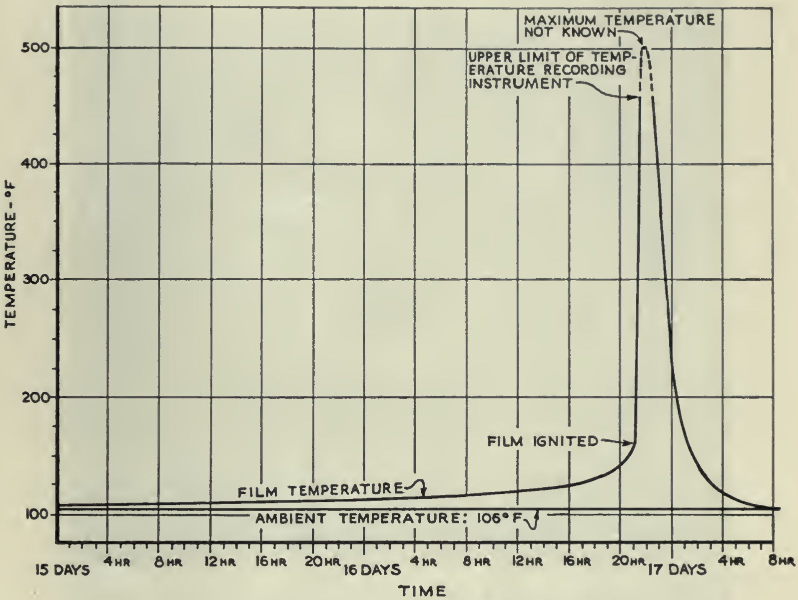

Fig. 3. Temperature during the critical period in which a film spontaneously ignited.

larly scheduled inspection of stored film stocks. Inspecting personnel should be trained to recognize decomposing film by appearance, with its condition classified according to the following categories. In the first stage of deterioration the photographic portion usually shows an amber discoloration with fading of the picture image. In the second stage, the emulsion becomes adhesive and the film convolutions tend to stick together during unrolling. Rolls of third-stage film have annular portions which are soft, contain gas bubbles, and emit a noxious odor easily recognizable. In the fourth stage of deterioration, the en-

tire film is soft, its convolutions welded into a single mass and frequently its surface is covered with a viscous froth. A strong noxious odor is given off, unmistakable to inspection personnel when once identified. In the fifth and final stage, the film mass degenerates partially or entirely into a brownish acrid powder.

Deteriorated film in the first and second stages is photographically reproducible. If the matter recorded is important, the film can be copied and the original disposed of. If the material is not valuable, the film should be disposed of at once. Adhesiveness prevailing in de-

Fig. 4. Sample of film in the third stage of decomposition.

teriorating film may cause the emulsion to become detached from the base while unrolling. This frequently can be prevented by slowly unrolling the film in a bath of carbon tetrachloride under precise laboratory control. This should be done only in adequately ventilated areas. In the third stage, only small portions of the film may be reproducible. The reproducible portions should be separated, if valuable, from the rest and copied. After reproduction, the entire original film should be immediately destroyed. In the fourth and fifth stages, film is photographically worthless and should be destroyed at once without further consideration.

Fig. 5. Sample of film in the fourth stage of decomposition.

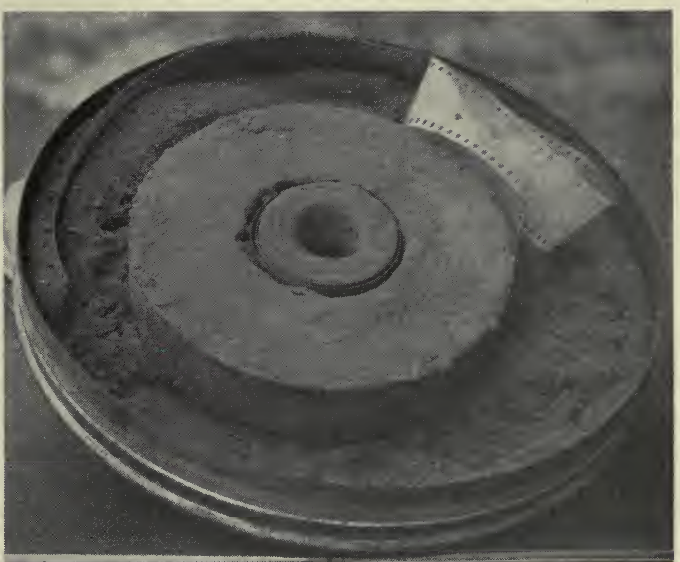

Fig. 6. Sample of film in the fifth stage of decomposition.

DISPOSAL OF DECOMPOSED FILM

Films of stages three, four, and five, designated for disposal, should be immediately submerged in water-filled drums. They should be carried in these drums to a remote, uninhabited area approved by fire authorities and destroyed by burning. The ground on which the film is to be burned should be free of brush, grass, leaves, and combustible litter. Burning should be confined to batches of not more than 25 lb, as the heat from the burning of large amounts of film creates a strong updraft which may bear fragments of burning film considerable distances to endanger neighboring properties. Under no circumstances should films be burned in an inhabited area or within a building. The rapid production of gases by burning film makes it extremely dangerous, particularly if burned in a furnace or confined space. During test fires in a well vented vault, engineers of the Interagency Advisory Committee for Nitrate Film Vault Tests have recorded pressures as high as 18 psi. It is readily understandable that no ordinary furnace structure could withstand this pressure; its breeching would fail and fill the furnace room with flames and poisonous gases.

PROTECTION OF PERSONNEL DURING INSPECTION

It is quite possible in the initial inspection that a relatively high proportion of film in advanced stages of decomposition may be found. The opening of cans containing this film may liberate quantities of noxious gases into the working area. Personnel exposed to them may experience nausea, headache, and other unpleasant symptoms if the ventilation is inadequate. It is, therefore, recommended that the personnel working on old film inspection be given ten-minute rest periods each hour in the outer air.

If we are to enjoy freedom from film fires during the coming summer, a comprehensive program of film inspection should begin now so that the task may be completed before the onset of hot weather. Since film is constantly subject to decomposition, inspection should be repeated annually, preferably in the spring. Only by such procedure can we avoid the insidious menace to life and property hidden in deteriorating motion picture film. Particular attention should be given to film of unknown quality or of obscure origin.

Sensitometric Aspects of Background Process Photography

By HERBERT MEYER

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Summary—The composite negative obtained by photographing action against a rear projected background is a combination of an original negative with a dupe negative. An analysis by sensitometric methods of the gradational distortions thereby introduced has been attempted, the results of which are discussed in this paper.

The advantages of background process photography over straight production technique consist generally in savings in location costs and in permitting a convincing picturization of supernatural effects. The same is true of a number of other photographic effect methods, all classified under composite photography, of which different types of matte processes are examples. A singular point which background process photography can claim as one of its distinguishing features is that the composite effect of background and foreground can be observed and evaluated prior to and during the actual photographing of the composite scene. As it presently stands, background process photography is but a small fraction of general motion picture production due to yet unsolved technical deficiencies and also on account of a somewhat reputed unpredictability of results. The combined advantages offered by this process are so obvious and substantial that its increased application seems highly desirable.

An investigation of the problems limiting the usefulness of background process photography in motion picture production has become one of the major projects of the Motion Picture Research Council. This rather basic study has not yet substantially advanced past the required preliminary work of evaluating available literature and technical knowledge represented by a store of practical experience in the studio transparency departments. This paper, therefore, is primarily confined to an analysis of some of the factors controlling the pictorial quality of the final composite obtainable with present methods. Such an analysis may contribute to the development of better meth-

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ods and equipment which eventually should make use of all the potential aspects expected of this process.

In parallel to the historic development of other phases of photography, background process technique has advanced, so far, on a purely empirical basis to a remarkable degree of performance. To develop this technique to greater efficiency, dependability and standard of quality, it becomes necessary to give it a clear and precise theoretical foundation.

Our discussion here is confined to black-and-white technique. It is further limited to the consideration of gradational requirements and problems of background process photography. This, therefore, excludes a treatment of such factors as definition, resolving power, graininess, etc., which are, of course, of vital importance in relation to the quality of the final pictorial reproduction.

Basic Problems Concerning Gradational Distortions

An analysis of the possible sources of gradational distortions reveals three major causes:

1. Duplicating Distortions

This type of degradation is an inherent property of any duplicating process, bringing about a shortening of the straight line part of the characteristic curve. It may, therefore, affect gradational qualities of the background image reproduced in the final composite negative or print and will do so equally over its total area. Duplicating technique in straight printing as performed in processing plants enjoys a relatively comfortable latitude in the variation of density levels and gamma values of the intermediate print and of the dupe negative to keep gradational distortions in the dupe positive to a minimum. Background process photography, however, is restricted to a much greater extent principally by the fact that the processing of a composite can give consideration only to an optimum gradation of one part of the composite. This means invariably favoring the gradation of the original foregound action negative.

2. Distortions Affecting Different Background Image Areas

This type of disturbance is evident in density and contrast variations between the central image areas and off-center areas of the background component. They are caused by various factors, not easily isolated for the determination of each one's specific contribu-

tion. Individually and in combination they reduce the image-forming illumination incident on the film progressively with increasing angles.

3. Distortions Caused by Flare

Flare is non-image-forming illumination incident upon the film during its exposure in the camera. If present in sufficient intensity it will cause degrading of contrast and brightness range. The most common source of flare encountered in background process photography is "leak" light reflected from foreground objects onto the process screen. Other causes, however, are suspected of contributing substantially to this type of degradation.

Comparative Importance of Gradational Distortions in Composite Photography

Ideal photographic reproduction of the projected background image requires by theoretical postulation linear density-brightness characteristics and an effective slope or gamma equal to unity. That this condition is not fulfilled in practice would, within reason, be just as acceptable as the common degradations in production release prints which probably never have straight line characteristics from clearest high light to deepest shadow. The adaptability of our aesthetic faculties apparently tolerates considerable deviations. However, as equally known from experience with other sensual observations, critical judgment becomes immediately acute in case a basis for a direct comparison of two even slightly different reproductions is presented to the eye. This is the case with composite prints in which the gradation of the foreground portion varies from that of the background portion.

Basic Elements of Background Process Technique

A brief outline of the principles of background process photography as practiced in studios is given here as an introduction to the later treatment of its gradational problems.

The original background negatives are usually photographed on locations selected for this purpose, in which case the use of a panchromatic, fine grain emulsion type is generally adopted. Sometimes, stock shots of older date and not originally intended to serve as background negatives have to be used. In either case, a print is made, normally in contact, of such negatives which becomes known

as the "process plate." The positive stock used for making this print is in most instances regular release print emulsion type with a normal positive gamma. A special fine grain print stock with considerably lower gamma characteristics is also used. The process plate is projected in a special background projector onto a translucent screen. The rear projected image is photographed together with the action in the foreground by a standard black-and-white camera.

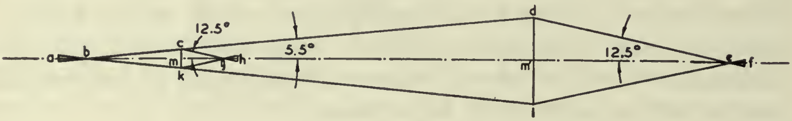


Fig. 1. Optical test arrangement (schematic).

Figure 1 is a schematic illustration of the optical test arrangement used in our experiments in investigating small process screen samples of different makes. An explanatory guide to the letter symbols used follows:

a	Projector film gate
ab	Focal length of projector lens = 5 in.
c	8 × 10 in. screen
ck	Horizontal screen dimension = 10 in.
bm	Distance between screen *c* center and projector lens = 3 ft $10^1/_8$ in.
mg	Distance between screen *c* center and camera lens = 1 ft $8^{35}/_{64}$ in.
gh	Focal length of camera lens = 2 in.
h	Camera film gate
d	30 × 40 in. screen
dl	Horizontal screen dimension = 40 in.
m'b	Distance between screen *d* center and projector lens = 15 ft $4^1/_2$ in.
m'e	Distance between screen *d* center and camera lens = 6 ft 10 in.
ef	Focal length of camera lens = 2 in.
f	Camera film gate

This arrangement was designed in exact correlation to the system commonly used in studio technique. Naturally, the figures for the distance between screen and projector and equally between screen and camera will increase proportionately with the size of the process screen employed. The projector and camera half-angles used in this illustration are co-ordinated to the focal length and aperture of the projector lens and of the camera lens respectively:

Projector half-angle, vertical:	4°	Camera half-angle, vertical:	9°
Projector half-angle, horizontal:	5.5°	Camera half-angle, horizontal:	$12^1/_2$°
Projector half-angle, diagonal:	7°	Camera half-angle, diagonal:	$15^1/_4$°

Use of a 5-in. projection lens and a 2-in. camera lens is representative of the most severe conditions under which background process pho-

tography is normally practiced. Wherever possible, lenses of greater focal length are employed to keep projection and camera angles as small as possible.

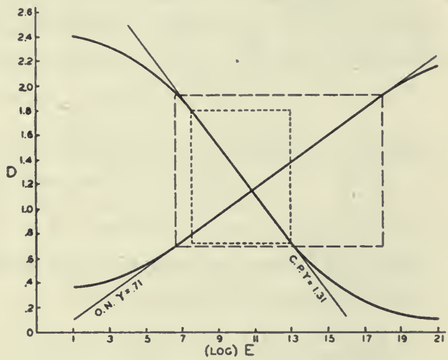
The gradational distortions to be discussed may be inherent in the "dupe negative"* alone or also in the process plate, both being the photographic media involved. The transmission characteristics of the process screen are all-important as factors influencing the gradational properties of the dupe negative. It therefore seems practical to treat briefly the photographic characteristics of the process plate separately and also to give special attention to the physical characteristics of diffusely transmitting objects in the form of the presently used translucent background screens.

PROCESS PLATE CHARACTERISTICS

Figure 2 shows the gradational characteristics of a sensitometric negative strip and of a contact print made from this negative. Ex-

Fig. 2.

Intensity scale (factor $\sqrt{2}$)
Original Negative (O.N.)
Contact Print (C.P.)
Negative density range (str. line), 1.22
Print density range (str. line), 1.08
Negative exposure latitude (str. line), 1:56
Print exposure latitude (str. line), 1:7



posure and processing for both original negative and contact print were closely matched to conditions which govern the making of process plates.

It will be noted that the linear portion of the printed curve is relatively short, being terminated at the lower densities by the characteristic curvature of the positive material, and at the higher densities by the inherent curvature of the negative material.

The over-all gamma value of 1.31 for the print is considerably above the postulated value of unity. This may be necessary for two reasons,

* By "dupe negative," as used from here on, is meant the rephotographed negative of the projected background plate. "Dupe print" signifies contact print from "dupe negative."

one of which is to obtain an over-all contrast close to unity, the other to compensate for contrast reducing factors encountered in projecting and rephotographing the process plate from the process screen. This would mean that to obtain an effective contrast value of unity, the process plate has to be developed to an over-all gamma of 1.31.

From the graphs it may further be concluded that an increase in print exposure which would shift the position of the print curve to the right should result in an expansion of its linear part, while a decrease in exposure will cause it to compress further. This would indicate that heavy prints are preferable for process plates. Insufficient projection illumination, however, limits the use of high density prints in many practical setups.

Process Screen Characteristics

The background process screens used at present are translucent media to be classified as imperfect diffusers.

The brightness or luminous intensity distribution over the area of such a screen type differs widely from that of a perfect diffuser that follows the simple cosine law of emission:

$$I(\theta) = I_0 \times \text{Cosine } \theta,$$

where, I_0 = Candlepower of the surface normal to itself ($\theta = 0$)
$I(\theta)$ = Candlepower at an angle θ from the normal.

An illustration[1] of the difference in transmission characteristics for various diffusing materials in comparison to the cosine function of a perfect diffuser is given in Fig. 3.

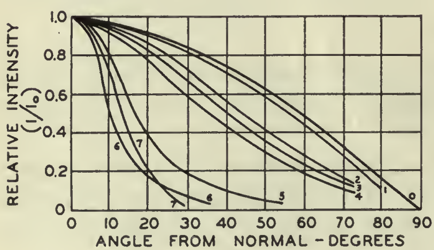


Fig. 3. Transmission characteristics of glasses.
0, Cosine curve
1, Solid opal glass depolished
2, Flashed opal glass, acid etched
3, Flashed opal glass, natural
4, Flashed opal glass, sandblasted
5, Clear glass, both faces sandblasted
6, Clear glass, one face sandblasted
7, Clear glass, one face acid etched

The rapid fall-off with increasing angle θ typical of imperfect diffusers is the main cause of the poor brightness distribution of presently available process screens. Unfortunately, the closer the translucent medium approaches the characteristics of a perfect diffuser,

the lower, in general, will be its relative transmission. In other words, gain in wide angle brightness distribution is accompanied by a loss in relative transmission or an increase in opacity. Figure 4 illustrates this dependence between transmission I_0 and $I(\theta)$ at a fixed angle of $\theta = 10°$ for several brands of commercial glass luminants with widely varying diffusing characteristics.

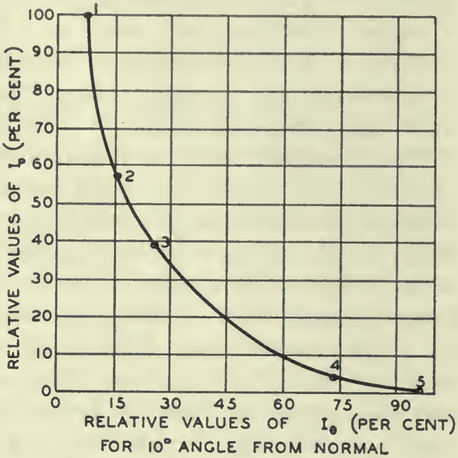


Fig. 4.
1, Factrolite
2, Tapestry
3, Maze
4, Sandblasted
5, Flashed opal

The angles encountered under practical conditions in 35-mm background process photography are within 15° for the projector side and 30° for the camera. The extreme angles stated are, however, quite frequently used of necessity. In some cases these angles may be still enlarged by the use of shorter focal length objectives, particularly for projection, when space limitations may leave no other choice.

The process screen type in use at present consists of a transparent cellulose acetate sheet which is sprayed on one or both surfaces with a layer of zinc stearate suspended in a solution of cellulose acetate. These layers serve as the diffusing medium which is, of course, needed to stop the projected image on the screen and make it visible and reproducible by photography. Each screen is handmade, and uniformity of transmission characteristics over the total area and from one screen to the other is therefore practically impossible to attain. The surfacing is accomplished by hand spray techniques which cannot assure even thickness of the coatings. The problem of uniformity becomes obviously more serious the larger the screen size. The transmission factor for $\theta = 0$ is determined in studio practice by simple comparative photometric readings of the amount of incident and transmitted light and serves as an indicator of the "speed" of the screen. Transmission readings made on a considerable number of screens at zero angle indicate that the luminous intensity of studio

screens varies in the range of from 55 to 70 per cent of the intensity incident upon the screen. The transmission characteristics determined by light meter readings are usually checked by means of a photographic density test. Such transmission readings serve in practice for guidance in arriving at a proper balance between level of screen brightness and foreground illumination. They are apt, however, to lead to erroneous calculations since they do not differentiate between specular and diffused transmission, and may also include light rays which do not reach the camera lens.

The present limitations in maximum light output of the background projector light source and optics make it necessary to increase the transmission of screens in direct proportion to their size, which the screen maker attempts by varying his spraying technique. Since it is desirable for various reasons to keep the light output of the projector constant, it is common practice to use denser process plates for smaller screen sizes. This means that for small screens with a relatively short throw, process plates of comparatively high density and low gamma are used, while for large screens and long throws, prints of relatively low density and high gamma are preferred. The over-all contrast of such different print types does not, of course, necessarily change by this procedure.

The transmission and light scattering characteristics of translucent screens have a large and multiple influence on the gradational characteristics of the composite photograph that is the end product of the background projection process. As it stands at present, practically nothing has been done toward a quantitative evaluation of these factors, with methods taking into specific consideration this field of background process photography. Much of the data available from literature on the subject of scattering of light[2] can be directly or indirectly utilized to great advantage in placing background process photography on a more efficient and reliable basis.

In addition, however, an extensive experimental investigation of materials and methods potentially suitable for making improved screens is indicated. Since the complexity of transmission characteristics of imperfectly diffusing media prevents the application of a clear mathematical treatment and since an additional photographic phase contributes to these difficulties, it seems fairly certain that direct practical experimentation studying size, refracting index, opacity, shape, distribution and other factors on a great number of materials will become unavoidable.

Practical experience in background process photography has, of course, established the validity of certain fundamentals which serve at present as rather general guides for screen makers and screen users. One of these, for instance, is the well-known observation that increase in diffusion decreases definition and contrast.

EXPERIMENTAL PART

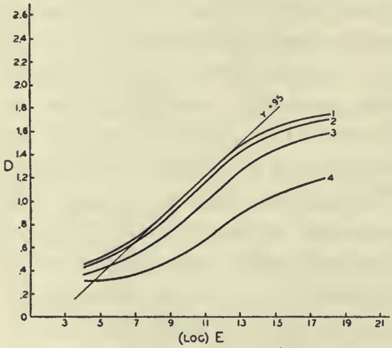
1. *Sensitometric Investigation of Typical Studio Procedure*

The original sensitometric negative strip and print referred to earlier and shown in Fig. 2 were produced for this experiment in the following manner. A studio 35-mm motion picture camera with single frame exposure device was aligned on an optical bench with a point light source as a photographic target. Single frame exposures were made in succession with full aperture and at a constant speed of $\frac{1}{48}$ sec. The distance of the light source from the camera was increased by precalculated values to result in exposures with intensities decreasing by factor $\sqrt[4]{2}$. The negative film type used was Eastman background emulsion. Processing by machine development was performed by Pathé Film Laboratories with instructions to develop to a customary negative gamma of 0.71. The developed negative was printed in contact onto Eastman Positive 1302 film and the resulting print developed for a control gamma of 2.15.

This print of an intensity scale negative strip was projected and rephotographed in regular background process procedure on a stage of the Universal-International Studios, together with pictorial process plates, and therefore is representative of the technique as presently practiced. The only exception to actual production conditions in background process photography consisted of omitting the inclusion of flare light from front illumination. The print was projected by a Mitchell background projector with a lens of 5-in. focal length onto a 9×12 ft process screen of the Sanders type from a distance permitting the projected image to fill the screen area.

The screen image was rephotographed by a standard 35-mm camera with a lens of 2-in. focal length and an aperture ratio of $f/4$. The camera was aligned with the projector and the center of the screen. The maximum off-axis angle formed by the projector was 7°, that formed by the camera was 15°. The resulting dupe negative was processed by machine development to a normal negative action control gamma of 0.67. A contact print from this negative was made

onto Eastman Positive Type 1302 on Light 11 and processed to a positive control gamma of 2.15. Figures 5 and 6 respectively show the density-log exposure graphs corresponding to both dupe negative and dupe print. Each of these figures depicts curves numbered from 1 to 4 which were obtained from density readings corresponding to various angles of illumination incident upon the film during exposure in the camera. It is quite apparent that for extreme off-axis image details, not merely a reduction in negative densities and a corresponding increase in print densities takes place, but also a pronounced change in curve shape and gamma compared with a curve constructed from the density readings of the image center.



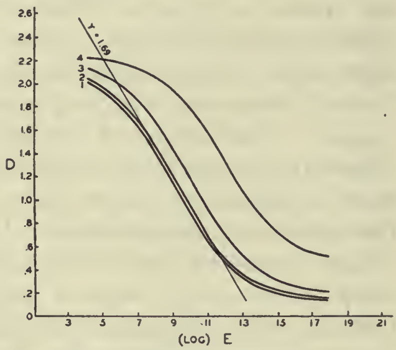


Fig. 5. Studio dupe negative.
1, Center readings
2, 5° angle off center readings

Fig. 6. Studio dupe print.
3, 10° angle off center readings
4, 15° angle off center readings

The progressive decrease in image-forming illumination on the film with increasing angles of incidence, which in turn resulted in the gradational differences shown in the above example, is mainly caused by the brightness fall-off characteristics of the process screen used.

The making of the process plate could not involve major off-axis distortions since in exposing the original negative the object was located on the optical axis so that vignetting and barrel effects as well as cosine[4] factor did not vary the image-forming illumination to any appreciable extent.

The background projector optics in this instance are adjusted to give a practically flat field for a half angle of 7°, and light meter readings of the radiation incident upon the screen did not vary more than 5 per cent from center to corner.

In rephotographing the projected image, stop $f/4$ was used which at least eliminates vignetting and barrel effects.

2. Sensitometric Testing of Different Types and Makes of Process Screens

A number of screen samples secured from three local fabricators were tested sensitometrically to determine and compare the influence of their transmission characteristics upon the gradational properties of photographic reproductions made in background process procedure. The test arrangement was similar to the one described and illustrated in Fig. 1. For the sake of simplicity and economy, and to obtain reproducible results in check tests, the following deviations from studio procedure seemed permissible.

As a projector, a factory-pretested Kodaslide still projector was used with an $f/2.3$ coated Ektar lens of 5-in. focal length. The illumination consisted of a 500-watt incandescent lamp operated at a voltage of 115 volts d-c which was carefully maintained throughout the tests.

The screen samples were uniformly kept to an 8 × 10 in. image area.

To obtain the process plate for this test, an 8 × 10 in. paper print of a step-wedge with six progressively increasing densities was photographed with a Contax camera on Eastman Background X type film and this negative developed to a gamma of approximate unity. The exposure was adjusted in such a way that the darkest field of the original step chart reproduced on the film with an approximate density of 0.40, the lightest field with an approximate density of 1.6 so that part of the film record registered on the lower curved portion of the characteristic curve of the film material. The image dimensions of the step-wedge reproduced on this film covered an area of only .25 × .06 in. in the center of the Contax picture frame. This frame was masked down to one-half standard 35-mm background projector aperture and projected in the Kodaslide projector onto the different 8 × 10 in. screen samples. At a distance of 69.5 in. between screen and projector, the screen image of the wedge extended lengthwise to the horizontal edges of the 8 × 10 in. screen. All stray light was masked off. This arrangement permitted projection with a maximum of central rays. The screen image was rephotographed from the back with an 8 × 10 in. view camera using an Ektar lens with 12-in. focal length and a 4 × 5 in. back. The film type selected for this purpose was Panatomic Cut Film. The film records were developed to a control gamma of 0.70. Exposure was kept constant for all tests and adjusted to the medium brightness level of all screens.

In rephotographing the projected screen images the camera was placed in two positions as follows:

A. Camera aligned with screen center and optical axis of projector. Distance between camera and screen center, 20 in. Placement of screen surface normal to optical axis of projector.

B. Camera moved parallel to screen with lens focused on center of screen until angle of 12½° between optical axis of camera lens and normal to screen was formed. Distance between camera and screen center, 21.5 in. Lens refocused for this distance. Placement of screen surface normal to optical axis of projector.

While this arrangement contains a number of unknown factors and does not permit a quantitative evaluation of the results, it was felt adequate in providing reliable comparative information which was the primary aim of this test.

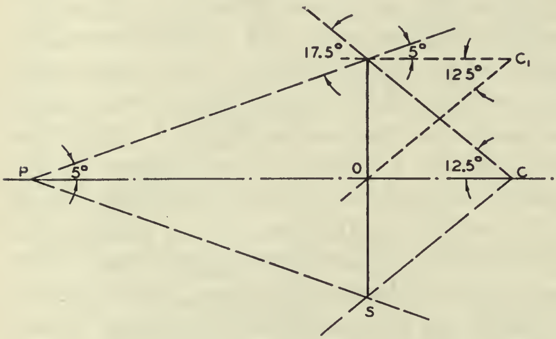


Fig. 7. (Not to scale.)

Figure 7 is a schematic illustration (angles not drawn to scale) of these two setups wherein C depicts camera position A, and C_1 camera position B. In both instances the optical axis of the camera lens meets the optical axis of the projector lens at the center O of the screen S.

The B-shot permits evaluation of transmission fall-off for a 12½° angle, characteristic of each screen. The arrangement was chosen to minimize factors causing additional brightness fall-off due to the projector optics employed. Naturally a slide projector of the type used does not give a similarly flat field as a specially corrected studio projector.

The step densities of each film record were read and the readings applied to construct density exposure curves. Since the factor of exposure progression was not known, the exposure scale is entirely arbitrary.

Table I lists for each screen and each camera setup the gamma readings and the density values of Step 1 (lowest density), Step 4 (medium density), and Step 6 (highest density). The gamma readings have, of course, no quantitative values. They permit, however, a comparative evaluation of the influence of each screen on contrast.

TABLE I

Screen Type	Relative Gamma Readings		Density 1st Step		Density 4th Step		Density 6th Step	
	A	B	A	B	A	B	A	B
1. Double*	1.60	1.61	.50	.42	1.16	1.05	1.90	1.82
2. Double	1.25	1.27	.44	.32	.95	.76	1.60	1.32
3. Double	1.46	1.45	.60	.43	1.19	.95	1.80	1.50
4. Double	1.48	1.40	.71	.45	1.31	.95	1.88	1.50
5. Single*	1.36	1.36	.74	.44	1.30	.85	1.88	1.44
6. Double	1.33	1.18	.48	.29	1.01	.64	1.65	1.17
7. Single	1.31	1.13	.62	.40	1.18	.82	1.70	1.32
8. Double	1.46	1.39	.44	.40	.96	.85	1.56	1.50
9. Double	1.42	1.50	.60	.45	1.17	.92	1.78	1.52
10. Double	1.22	1.33	.95	.80	1.35	1.15	1.84	1.80
11. Double	1.49	1.48	.58	.43	1.17	.97	1.80	1.58

* Double = double surfaced; Single = single surfaced.

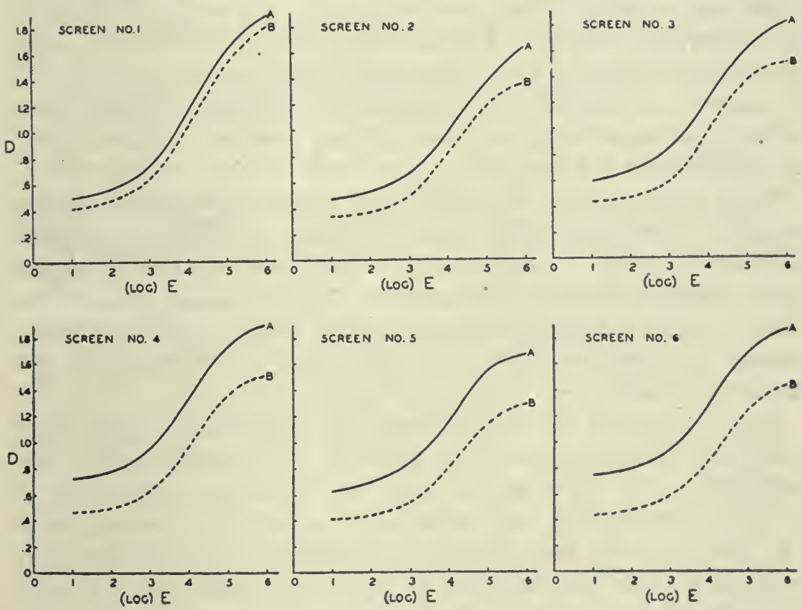


Fig. 8.

Figure 8 shows graphically these density curves for six selected screen types corresponding to Screens No. 1 to 6 of Table I. The solid line curves are constructed from densities obtained with A-shots (camera on optical center). The dotted line curves were plotted from densities obtained with B-shots (camera 12½° angular position). As will be noticed, the six selected screen types are progressively worse in fall-off characteristics.

In studying and analyzing the data contained in Table I, a clear relation between fall-off characteristics and relative transmission of the screens could not be established, nor was it possible to find a simple function of contrast in relation to relative transmission. This result is rather disappointing and emphasizes the complexity of factors under which background process photography has to be practiced at present. The irregularities observed, however, make it practically certain, in an indirect way, that more efficient screens can be constructed, that is, screens with optimum relative transmission (speed) and still relatively favorable angular fall-off characteristics.

Conclusions

The tests described in this paper were primarily selected out of a rather large series of similar tests performed in the course of this project, to exemplify the type of studies that have so far been undertaken. They further illustrate the problems that have been encountered and are expected to be faced in continuation of this work. Finally, they indicate the manifold factors and phases that are left for further experimentation and analysis.

While improvements of present type process screens and process technique appear entirely feasible, they may not lead to ultimately satisfactory results unless the complications and limitations of imperfectly diffusing screens are eliminated. This indicates a search for different types of projection screens which, while not included in the present discussion, is also under continuous consideration by the Research Council.

At this stage it is too early to make any suggestions or predictions concerning the development of basically new process screens and techniques. An investigation into the potential application of directional screens has been undertaken as part of our general project. However, the large size screens demanded for motion picture production work and the trend of making increased use of camera movement in front of the projected background present severe diffi-

culties and limitations in the manufacture and use of directional screens.

Acknowledgments

We wish to express our appreciation to Universal-International Pictures Inc. and 20th Century-Fox Film Corp. for their liberal assistance extended to the Research Council in the staging and processing of our experimental work. We also acknowledge valuable information and suggestions given to us by Farciot Edouart and Dr. Charles Daily of Paramount Pictures Inc. and William Slaughter of Metro-Goldwyn-Mayer Studios. Special mention is due Stanley Horsley, of Universal-International Pictures, for his untiring efforts and interest in this project. He also guided the design of our test equipment and supervised the control tests made at that studio.

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A Motion Repeating System For Special Effect Photography

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Summary—This is a motion reproducing system for use in "special effect shots" (multiple exposures, matte paintings, pan and tilt traveling matte shots, etc.) which permits the change of a camera position and adjustment while photographing a scene. Then, with the film rewound to the original starting point, a second exposure is made on the same film of a second scene, duplicating the relation of camera position and adjustments to the film movement which existed while photographing the first scene. This is done with sufficient accuracy to match matte lines in any of the standard double-exposure or other similar effect shots.

With modern studio equipment the camera is free to move about, follow the action, and graphically and pleasingly describe the scenery and tell a story. But all this freedom of camera movement does not help the makers of special photographic effects, because some processes require that the camera be fixed, as the film is run through the camera several times and the image of one exposure must be positioned in exact relation to the other parts of the picture previously exposed. When cut into a picture that has been photographed by a roving camera, the effect shot, by comparison, may seem static and lifeless regardless of how well conceived and executed.

Some double exposure and matte shots have been made with the camera moving mechanism and the camera film-moving mechanism geared together. By beginning each take with the film and camera positioned on a start mark, the camera position will be the same for each picture frame, as the film passes through the camera for any number of operations. The use of this system is limited because the rate of movement must be predetermined and the action must follow the camera, which is an awkward, and sometimes an impossible, procedure.

A system for special effect shots has been devised and applied at present to panning and tilting the camera, which permits the cameraman to pan and tilt the camera in a normal manner and follow the action as desired. A record is made of the movement and, for subsequent exposures on the same film, the record controls the camera

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movement, matching the original relation between the camera position and picture frame during these subsequent exposures.

In this system the camera is moved by the output shaft of a differential gear system. Two synchronous motors are connected to this gear system in such a way that the output shaft rotates at a speed which is the difference in the speed of the two motors; in other words, if the two motors were connected to the same power source, the difference in speed would be zero and consequently the speed of the output shaft, which moves the camera, is zero and the camera is stationary. However, if one of the motors is connected to a power supply of a different frequency, the camera is moved at a rate that is in proportion to the difference of the frequency of the two sources.

In operation, one of the synchronous motors is connected to the electric power system and runs in synchronism with the power line frequency; the other, whose change in speed causes the camera to move, is fed by an amplifier and runs in synchronism with a control signal which is fed to this amplifier. This control signal is produced by an induction frequency changer. The three-phase primary of this frequency changer is also connected to the electric power system. With this type of frequency changer, the output frequency is the same as the input when the rotor is at standstill and increases in proportion to the speed of rotation if the rotor is revolved in one direction and decreases proportionately if reversed. Therefore, the camera movement follows the rotation of the frequency changer shaft.

This control signal is also fed to a recording system and recorded when the first take is made.

A "start mark" is placed at the beginning of the record and the beginning of the picture film. The recording machine and the camera are driven by a common-drive source so that they accelerate and run together and the length of the picture film and the record are in proportion through the running.

For subsequent running of the film through the camera, the camera and record-reproducing machine are lined up with their respective start-marks as they were at the beginning of the first running and are driven by a common-drive system. The signal, which is fed to the amplifier driving the variable-speed synchronous motor, is reproduced from the record. Being identical in respect to frequency to the original signal from the frequency changer that produced the camera movement during the first run, the camera moves as it did during the first run. Thus, as each picture frame is moved into the photo-

graphic aperture, the camera is in the same position and angle as it was when that picture frame passed through the camera the first time. The camera is held in a fixed position for a short time at the beginning of the shooting. On subsequent running of the film this time interval is used to check and correct the camera position.

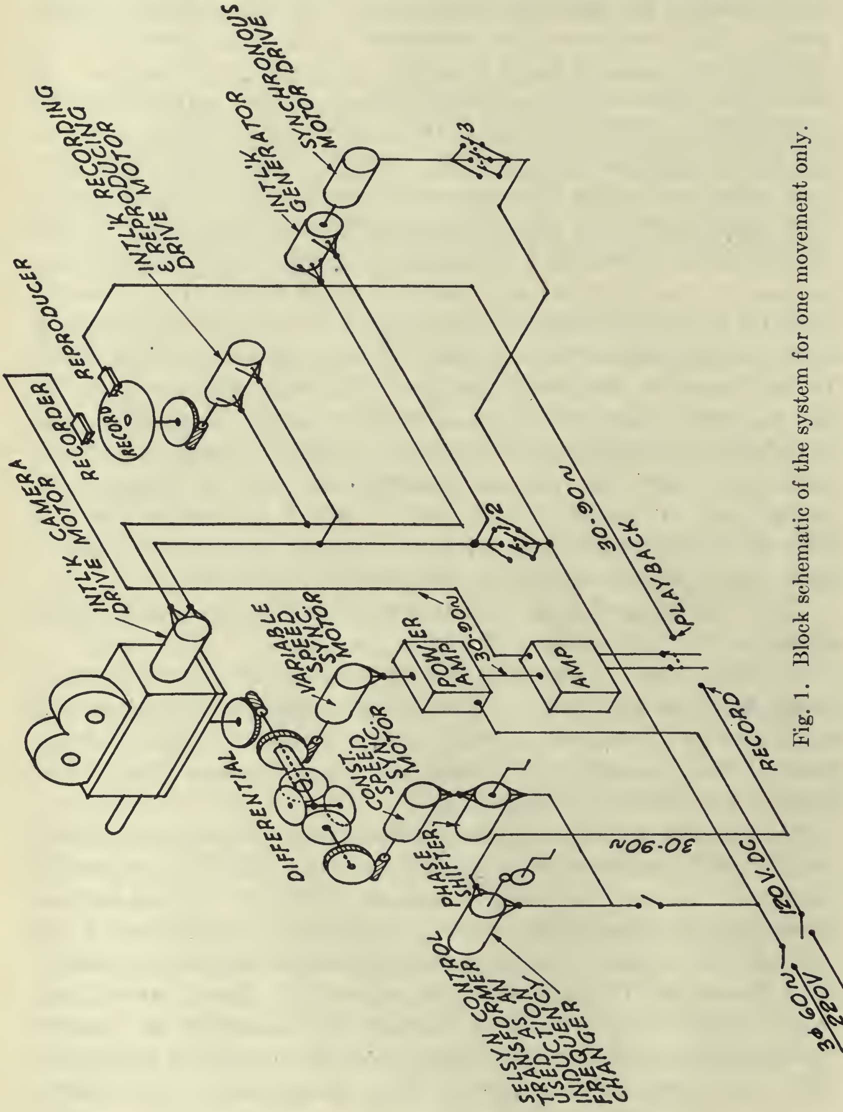

Fig. 1. Block schematic of the system for one movement only.

Fig. 2. Motion repeating machine for Technicolor camera, with Bell & Howell camera adaption.

Fig. 3. Recording and reproducing equipment and controls, with all electronic equipment mounted in portable cabinet.

The phase angle of the signal from the disc may vary a few degrees from the original signal; so after everything is up to speed this error is corrected by means of a phase shifter which is inserted in the constant-speed synchronous-motor line.

The common-drive system that is mentioned is the same electrical interlock system that is used in sound picture work to hold the picture and sound systems in synchronism for sound picture making and reproduction. It is also used to hold the camera and projection machine shutters and film movements in synchronism for making projected background process shots.

Figure 1 is a block schematic of the system showing, for simplicity, one movement only for panning the camera. A duplicate system is provided to elevate and depress the camera. Both records are made simultaneously on one disc. A system similar to the standard phonograph disc recording and reproducing system was used to record and reproduce the control signal.

The power amplifier which supplies the power to the variable-speed synchronous motor is in this application a thyratron inverter. This system is ideal for this job because variations in input voltage have no effect on the output voltage, provided the input voltage stays above the minimum necessary to fire the thyratrons. Also, the simple circuit used produces the necessary change of output voltage with frequency to operate a synchronous motor, at full torque, at all frequencies. Ample power is produced using the 120 d-c studio lighting power as a "B" supply.

Errors due to the shifting of synchronous-motor rotor poles, in respect to the applied frequency as it takes a load, are reduced by a factor of 800 to 1 in the gear train. A large portion of this displacement occurs when the motor accelerates or decelerates the camera, and as the motor has the same mass to move at the same point of its movement no visible error in duplication of movement due to this has been observed at any time. The present maximum rate of pan and tilt speeds is about 25 degrees per second, which is faster than any requirement encountered at present.

Mr. Richard Duval of the Development Engineering Department of Metro-Goldwyn-Mayer Studios has worked out lens position charts for the changing of focal settings between various shots.

Using a painting as the second subject photographed, a change of ten to one in focal distance has been made with no relative movement between the images photographed at these two settings.

Increased Noise Reduction By Delay Networks

By J. R. WHITNEY and J. W. THATCHER

Sound Services, Inc., Hollywood, Calif.

Summary—This paper describes a new method of obtaining increased signal-to-noise ratio in optical sound film recording. This is done by increasing the noise reduction and is made possible by the use of delay networks which delay the application of sound currents to the modulator until after the noise-reduction-bias current has been partially canceled. Noise-reduction settings as high as 30 db have been tried with good success and settings of 15 db have been used in regular production.

Recent developments in original sound recording such as 200-mil push-pull optical tracks and magnetic films have made original sound records far superior to the release tracks which are heard in the theater. Since it undoubtedly will be many years before anything except the standard non-push-pull optical sound tracks will be used in theaters, anything which will improve the quality of release tracks would be highly desirable.

One relatively easy way of improving the release track would be to increase the noise reduction now being used in all optical film recording.[1] However the use of noise reduction brings in some inherent disadvantages such as "clipping" and "thumping." Clipping is caused by the modulator overloading for a few syllables when sounds with sudden impacts are being recorded, because the cancellation of the noise-reduction-bias current takes an appreciable length of time. If this time is shortened too much in an effort to reduce clipping then the operation of the modulator by the noise-reduction currents approaches audible frequencies and thumping occurs. In practice the noise reduction unit is adjusted for a practical balance between clipping and thumping which together with the use of "margin" makes these sounds generally unnoticeable. Margin is the adjustment which determines the difference in decibels between the signal which just overloads the modulator and the signal which just cancels the bias current.

One method of reducing these undesirable noise-reduction effects

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so that increased noise reduction could be used would be to delay the application of the signal currents to the modulator until after the noise-reduction currents were partially canceled. Up to the present time this has not been practicable but with the newly developed Delay Network designed by the Bell Telephone Laboratories it has now become possible.

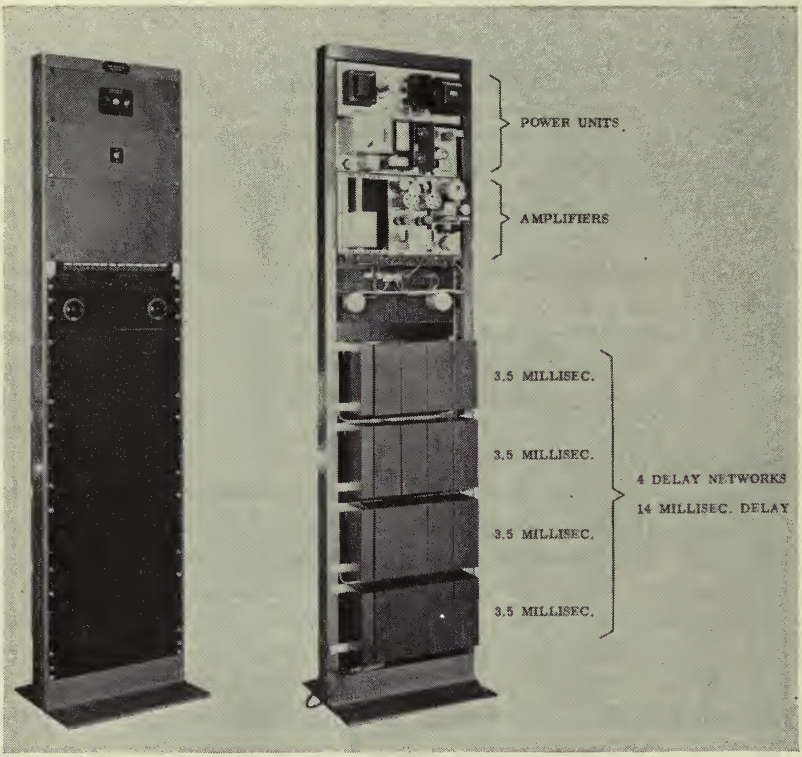

Fig. 1. Delay network rack, front and rear views.

For several years delay networks have been used in radio receiving systems, automatic recording oscillographs, transoceanic radio telephone service and radar.[2] The design of delay networks is based on the principle that electrical energy supplied to inductances and condensers can be stored for an appreciable length of time in the electromagnetic and electrostatic fields of the coils and condensers. This storage creates a time delay between the receipt of a signal at

the input to the network and its delivery to the output. If the network is designed to have different amounts of delay at different frequencies it is called a delay equalizer; while if it is designed to have a constant delay for all frequencies it is usually referred to as a delay network. It is relatively easy to design a delay network to cover a limited band of frequencies but it is very difficult to design one which will cover the full audio-frequency band. The new networks are designed to cover the frequency range of 50 to 8000 cycles and have been made possible only by the great amount of experience gained by the Bell Telephone Laboratories in recent years in designing delay networks. Each network has a constant attenuation of about 13.5 db and a time delay of 3½ milliseconds. Delay times in multiples of 3½ milliseconds can be obtained by using the networks in series.

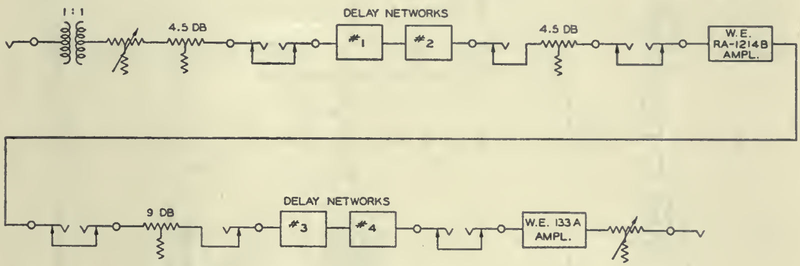

Fig. 2. Delay network rack, block diagram.

For reasons explained later it was decided that in production sound recording, four networks in series, having a time delay of 14 milliseconds, would be used. These networks, together with the necessary amplifiers, power units and attenuators, were assembled on a rack (Figs. 1 and 2). The delay network rack circuit was designed to have a zero insertion loss and enough output capacity to drive a light-valve modulator. On the recommendation of the Bell Telephone Laboratories the circuit was so designed that no network would have an input power exceeding zero dbm. Following good engineering practice, the networks are isolated by attenuators from possible variations in impedances. As shown in Fig. 3 the delay network rack is patched into the re-recording channel just ahead of the modulator and after the noise-reduction-amplifier input bridging point. In this way the speech currents are applied to the noise reduction amplifier 14 milliseconds before they arrive at the modulator. By

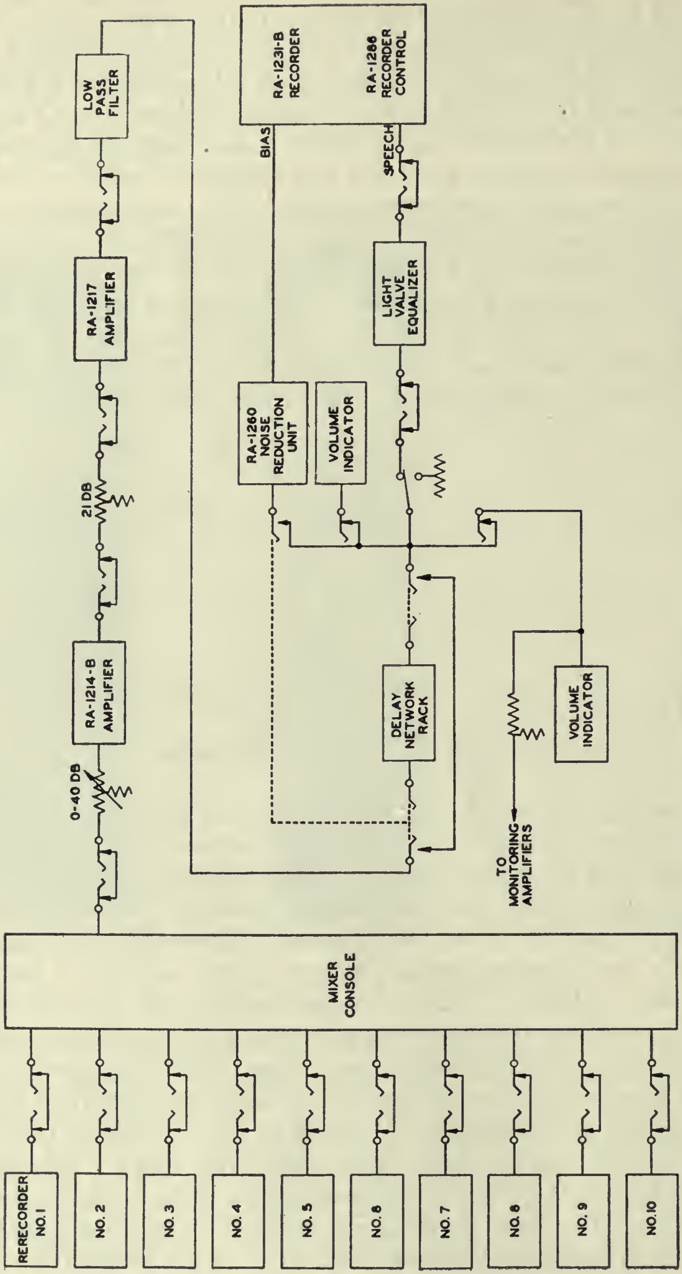

Fig. 3. Re-recording channel with delay networks, block diagram.

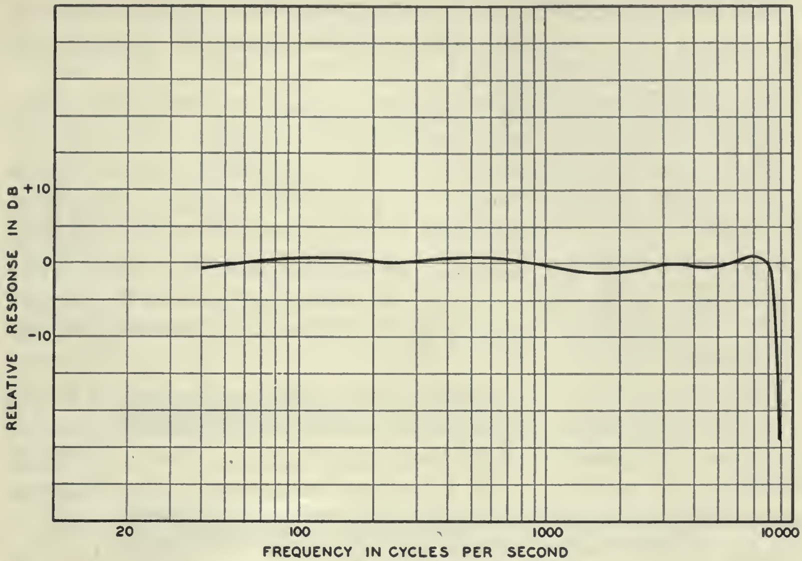

Fig. 4. Delay network rack, frequency characteristic.

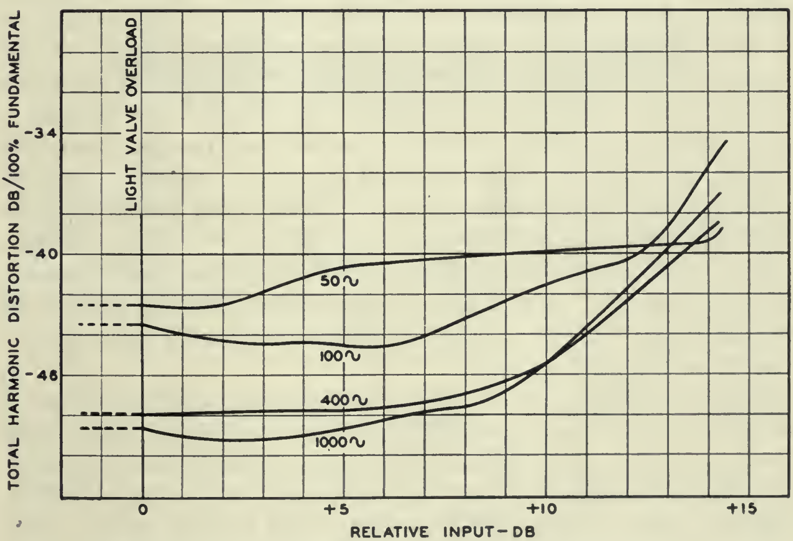

Fig. 5. Re-recording channel, harmonic distortion.

having the network rack have a zero insertion loss, it can be removed or inserted in the channel without the necessity of changing the channel operating adjustments.

The gain frequency characteristics of the network rack is within ± 1.5 db over the range of 50 to 8000 cycles (Fig. 4).

Distortion measurements made on the re-recording channel, which was a regular Western Electric 435 D re-recording channel using an RA-1231 B recorder and RA-1251 B re-recorders, show that including the delay networks the distortion for any frequency above 50 cycles is less than 1% for inputs up to 9 db above the light-valve overload point. At light-valve overload the distortion at the same frequencies is less than ¾% (Fig. 5).

After considering the possible uses for delay networks in a sound recording channel, it was agreed that the most advantageous use would be to increase the signal-to-noise ratio in release prints. While the networks could be used to reduce undesirable noise-reduction effects such as clipping and thumping, it was believed that an increased release volume range was preferable. Consequently, our tests have been limited to that field.

A normal noise-reduction setting for single variable-density recordings is 10 db with the noise-reduction filtering adjusted for an attack time of from 16 to 22 milliseconds. Attack time has been defined as the time required for the bias current to undergo 90% of its total change when a signal having a magnitude somewhat less than the value required to cancel the bias fully is applied to the noise-reduction unit. Since the movement of the light-valve ribbons is proportional to the amount of current flowing through them, the average spacing of the light valve will be directly related to the bias current. The characteristics of the noise-reduction timing filter on attack signals are such that the rate of opening of the biased light valve is not constant but is greatest at the beginning and decreases to zero at the end. For a given noise-reduction timing, the rate of opening varies with the noise-reduction setting, being faster for increased noise reductions.

Since it was planned to use high values of noise reduction and since the rate of valve opening was to be retained at about the same value as was normally used, the timing filter was modified to have an attack time of about 24 milliseconds or about 25% longer than normal. With this filter and a noise-reduction setting of 15 db, the rate of valve opening is about the same as with a normal 19-millisecond filter and a

setting of 10 db. With the modified filter, the valve opens to 41% of its average spacing in 14 milliseconds (Fig. 6).

With a delay time of 14 milliseconds and with the modified filter, it was calculated that the valve could be completely closed and that less clipping of initial sound would occur than with normal operation at 10-db noise reduction. With this in mind, re-recording tests were made with music and dialogue with noise-reduction settings of from 0 to 30 db and with margin settings from 0 to 6 db. These tests showed that the use of high values of noise reduction was entirely feasible although as much as 30 db was undesirable since at that value the sound quality began to deteriorate somewhat. These tests also indicated that margin settings greater than zero were unnecessary

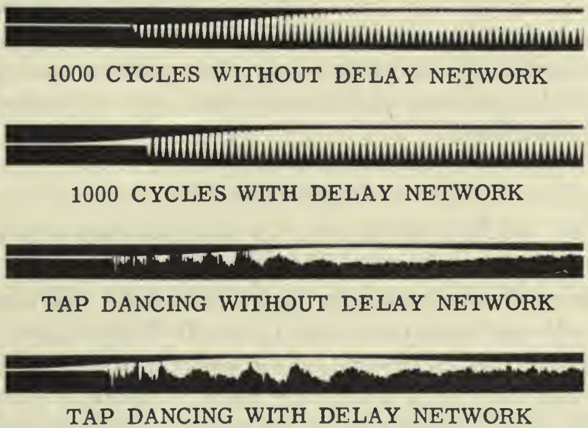

Fig. 6. Sound tracks with and without delay networks.

to prevent clipping, although the use of up to 6 db of margin caused no harm. However, the decrease in film noise made 96-cycle sprocket-hole modulation more apparent. For this reason it was decided to use a value of 15-db noise reduction for actual production re-recording.

Sound Services, Inc., have been using this value of noise reduction for over a year with various types of product with completely satisfactory results. In a number of cases the increased noise reduction has been very helpful in allowing a decrease in the normal recording level so that special effects could be obtained.

While most of our experience has been with density recording, we have also used the networks with success in variable-area recording. Here the problem is one of obtaining as narrow a bias line as possible

without getting excessive clipping action. In order to reduce the low-frequency thump action which would have been accentuated by the increased rate of change of the noise-reduction ribbon due to the smaller valve spacing, it was necessary to increase the attack time of the noise-reduction filter as was done for density recording. An attack timing of 32 milliseconds was used.[3] With no other change, we were able to bias down to a bias line on the film of 1 to 1½ mils with good results. Experience with this small bias line has shown that films that have been projected many times in theaters still exhibit very little film noise.

While a good deal of practical experience has been obtained in the use of 14 milliseconds of delay, no extensive investigations have been made regarding optimum time of delay, the best speed and type of noise-reduction attack timing, or the practical limits to the amount of noise reduction which can be used. Tests such as these should be made in the laboratory and the conclusions tried out under practical operating conditions.

Conclusions

Delay networks with a time delay of 14 milliseconds over the audio-frequency range of from 50 to 8000 cycles have been used in sound film recording to obtain additional noise reduction. Through the use of these networks noise reductions up to 30 db have been tried and 15 db has been used in production for a period of over a year. One of the limiting factors in using more noise reduction is sprocket-hole modulation which becomes more objectionable as noise reduction is increased. The use of the delay networks is advantageous in both variable area and variable density recording. They are especially desirable since the improvements gained through their use are obtained in the final release negative.

NOTE: The presentation of this paper was supplemented by a demonstration film which was designed to show the possible uses of high noise reduction.

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Miniature Condenser Microphone

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Summary—This paper describes a miniature microphone that has been reduced in size so that an extremely uniform frequency response is obtained from all angles of pickup. Although it is very small its output level is high. Because it is so small, it can be used in many applications not possible with larger and heavier microphones. Uses of the microphone in motion picture sound recording indicate a different placement and pickup technique can be used. Having simple parts, its uniformity of production can be extremely high. A description of different models is given along with suggested methods of using the microphone.

DOLBEAR described a condenser microphone in 1882 and such a device was reported as being shown at "La Lumière Electrique" in 1881.[1] Later Wente[2] produced a commercial unit which had extensive application in the first years of sound motion picture recording. It was then replaced by dynamic, ribbon and directional microphones. Later smaller condenser microphones were described by H. C. Harrison and P. B. Flanders[3] and also by F. L. Hopper.[4] The principal objections to the early condenser microphone designs resulted from such factors as: (1) diffraction effect due to its comparatively large size; (2) cavity resonance; and (3) electrical circuit complications.

In using a microphone the sound reaching it directly is, in most cases, only a very small part of the total. Most of the sound arrives from random directions, the amount being picked up directly depending upon the reverberation of the room and the distance from the source. When the microphone has a response which differs in the various directions, the output fails to be an exact reproduction of the source. Under these conditions, one form of distortion is introduced by the microphone. The directivity of pressure type microphones, such as condenser type, results from two factors: (1) the variation of the diffraction effect and the angle of pickup; and (2) the decrease in pressure caused by phase shift which occurs when the direction of the sound has a component which is parallel to the plane of the diaphragm.

Each of these effects is a function of the size of the microphone relative to the wavelength of sound.[5]

PRESENTED: October 14, 1949, at the SMPE Convention in Hollywood.

DIFFRACTION

An extremely small size of the microphone is required in order to minimize the variations in directivity with angle. If this effect is to be held negligible ($\pm$ 1 db at 10,000 cycles) the diameter of the microphone must be approximately no greater than ½ in. The diffraction effect is the more important of the two factors described above, where the wavelength becomes comparable to the diameter of the diaphragm. This is the effect which makes a difference between the "free field" and the "sound pressure" measurement calibration of a

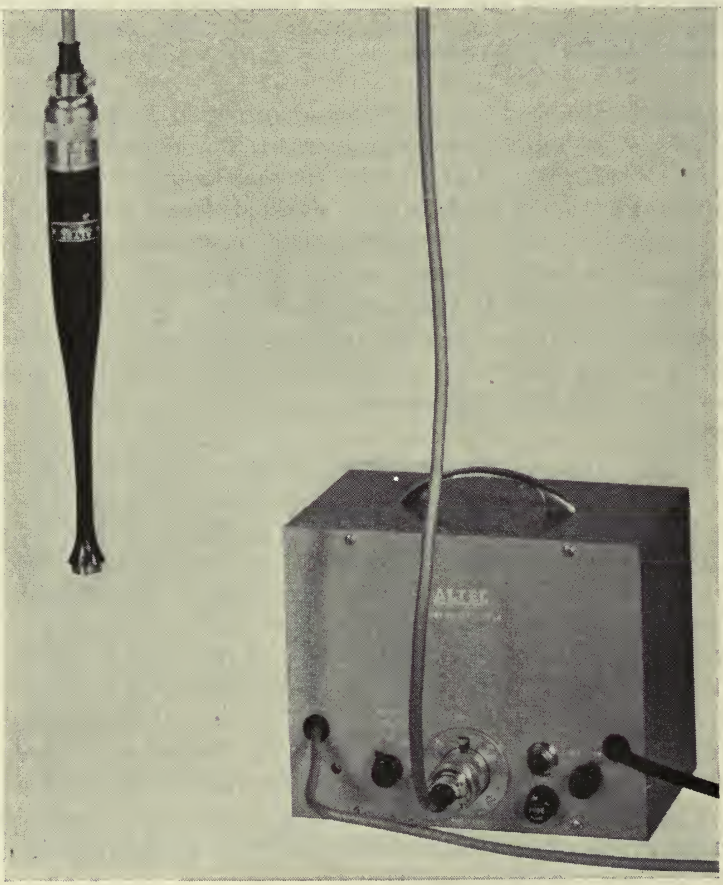

Fig. 1. M11 microphone system.

microphone. With these unescapable fundamental principles established, there appears to be only one way in which diffraction distortion can be reduced to a negligible degree, and that is maintaining an extremely small size. Calculated diffraction effects have been checked very closely with data obtained from "free field measurements."

The two most commonly used types of housings for pressure operated microphones are the cylinder and the sphere.

When a microphone is built to have the fundamental shape of a cylinder, the diffraction effect is such that when sound arrives perpendicular to the end of the cylinder which represents the diaphragm (upper part of Fig. 2), the response increases by a factor of approximately 8–10 db when the ratio of the diameter to the wavelength of sound is unity. At frequencies above this point, a series of variations by this same amount occurs at intervals. In the case of a sphere

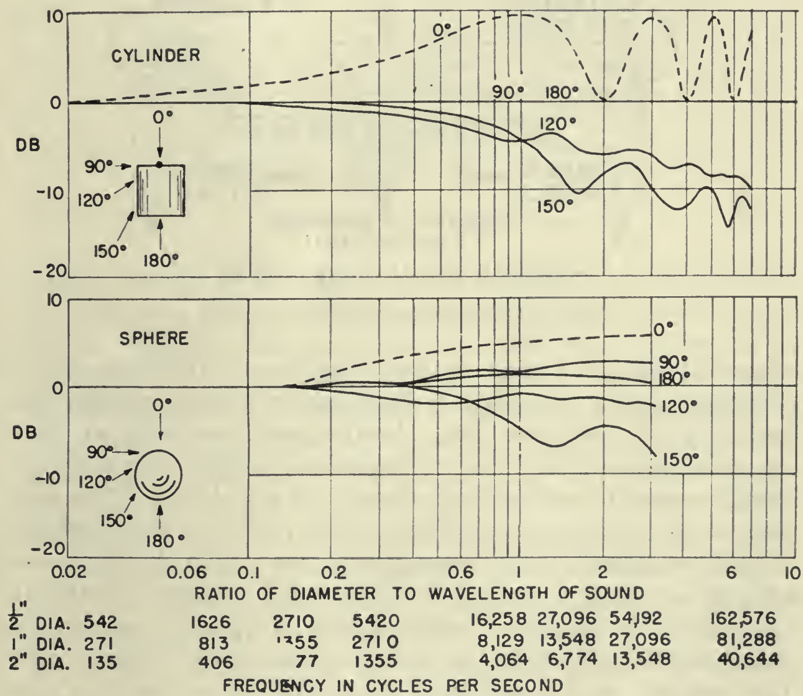

Fig. 2. Effect of diffraction.

(lower part of Fig. 2), the output perpendicular to the axis is uniform at a value equal to that for a ratio of the diameter to the wavelength of unity. The cylinder shows a larger variation than the sphere which has a minimum variation of 12 db when the ratio of diameter of wavelength to sound is greater than 1.5. These data indicate that while it might be technically possible to equalize the on-axis response to be uniform, a variation of not less than 12 db will be encountered for the various angles of pickup for this ratio.[6,7]

DESIGN

Having established the fact that miniature size is a necessary requirement to reduce this form of distortion, effort has been directed to design and produce a commercial microphone meeting the requirements of size along with sufficient output to maintain the necessary signal-to-noise ratio. Figure 3 shows a cross-section diagram of the

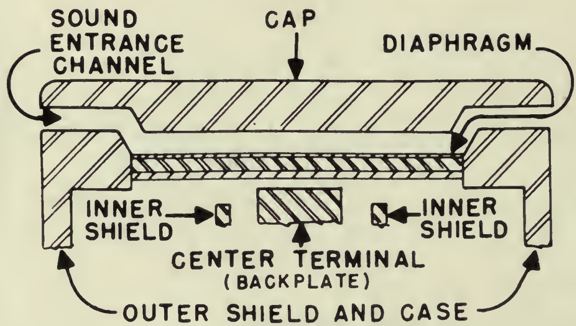

Fig. 3. Cross section of 21B microphone.

essential portions of this miniature microphone. They consist of a diaphragm and an electrode or backplate in close proximity. The backplate and diaphragm being closely spaced, constitute an electrical capacitance which varies with microscopic deflections of the diaphragm caused by pressure variations in the sound wave. The backplate or center terminal is polarized with respect to the diaphragm through an extremely high resistance so that a fixed charge accumulates on the center terminal. As the sound pressure actuates the diaphragm, the capacity of the microphone varies and a corresponding change in voltage between the center terminals and diaphragm exists. The resulting signal is applied to the grid of the vacuum tube which follows. The surface of the diaphragm facing the center terminal is

formed of insulating material, eliminating the problem of electrical breakdown between these parts.

The microphone base encloses a 6AU6 Miniature Vacuum Tube whose function is to translate the change in voltage generated by the microphone across an extremely high impedance to a nearly equal voltage across an impedance of 1200 ohms so that the signal can be faithfully transmitted over lengths of cables to subsequent apparatus. The circuit of the impedance transferring tube in the base is shown in Fig. 4. The microphone backplate receives its polarization through the elevation of cathode voltage above ground potential. It is a property of the cathode follower circuit that its input impedance is extremely high whereas its output impedance is relatively low.[8] Also, the effect of any capacity connected between cathode and grid is

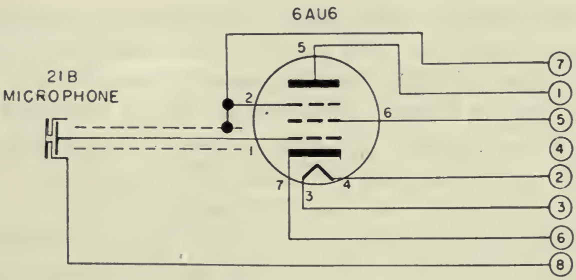

Fig. 4. 150A microphone base.

greatly reduced by the cathode follower action. Connections of the inner shield in the microphone permit it to be separated by a short distance from the vacuum tube. The extension between vacuum tube and microphone is intended to achieve the fullest advantage of the miniature size of the microphone without providing any additional obstacle size and its associated distortion. The microphone base contains only the cathode follower vacuum tube. All other components associated with it are located at the far end of the interconnecting cable. This is done to maintain the smallest possible base size.

The dimensions of the microphone are .6 in. in diameter and .4 in. thick. It weighs approximately 6 grams. A small circumferential sound entrance channel, 20 mils thick, is located on the side of the microphone. This aids in maintaining an omnidirectional characteristic and provides protection against mechanical damage to the diaphragm. The microphone is mounted on a base which is $8\frac{3}{16}$ in.

long and has a diameter of $1\frac{1}{8}$ in. at the bottom which has a Cannon P-8 Plug. The top of the base is $\frac{13}{16}$ in. in diameter. Since the top of the base is smaller in diameter than the microphone, it does not contribute any added obstacle interference.

The microphone and its base are connected to the power supply by means of a cable (up to 400 ft in length) whose construction is shown in Fig. 5. Signal transmission through this cable is equivalent to the use of coaxial cable. The three inner conductors which carry the signal have high capacity between them in the circuit. The outer conductors carry the other tube functions all of which are at ground potential for the signal. By this construction, the outer conductors serve to shield the inner signal conductor.

POWER SUPPLY

The power supply cabinet houses the components associated with the vacuum tube in the base as well as the output matching transformer, and the plate and filament power. The circuit of the power supply is shown in Fig. 6. Rectifiers are the selenium dry disk type and supply the necessary plate and screen voltages along with the heater current for the 6AU6 Cathode Follower Tube. While the cathode follower has a low output impedance, it must work into a load of relatively high impedances in order that it function properly. In this case, a load of 70,000 ohms is used. The matching transformer is then used to transform this impedance down to conventional values used in pre-amplifiers.

DESIGN CHARACTERISTICS

In the past a reduction in size of the microphone has lowered the sensitivity to such an extent that an adequate signal-to-noise ratio could not be maintained. In this microphone the sensitivity is, in spite of its size, sufficient to give -48 db below 1 milliwatt for a sound field of 10 dynes/sq cm at the output of the transformer. The open circuit voltage of the microphone is -50 db below a reference of 1 volt/dyne/sq cm. The electrical capacitance of the microphone is approximately 6 micromicrofarads. The diaphragm is 0.5 in. in diameter and is clamped on the edge. Since it is of laminated construction and part is composed of insulating material, its resonance is not determined by tension.

The frequency response of the microphone, including all apparatus up to the output of the matching transformer, is within 1 db from 40

cycles up to 12,000 cycles. Because of the simplicity of the mechanical and acoustical elements in the microphone, a very high degree of uniformity can be maintained between production units. This uniformity can be observed by placing two microphones immediately adjacent to each other. By connecting their outputs so that they are out of phase, a sound source will be canceled by a factor of approxi-

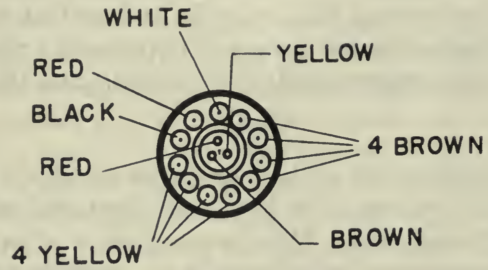

Fig. 5. Cross section of microphone cable.

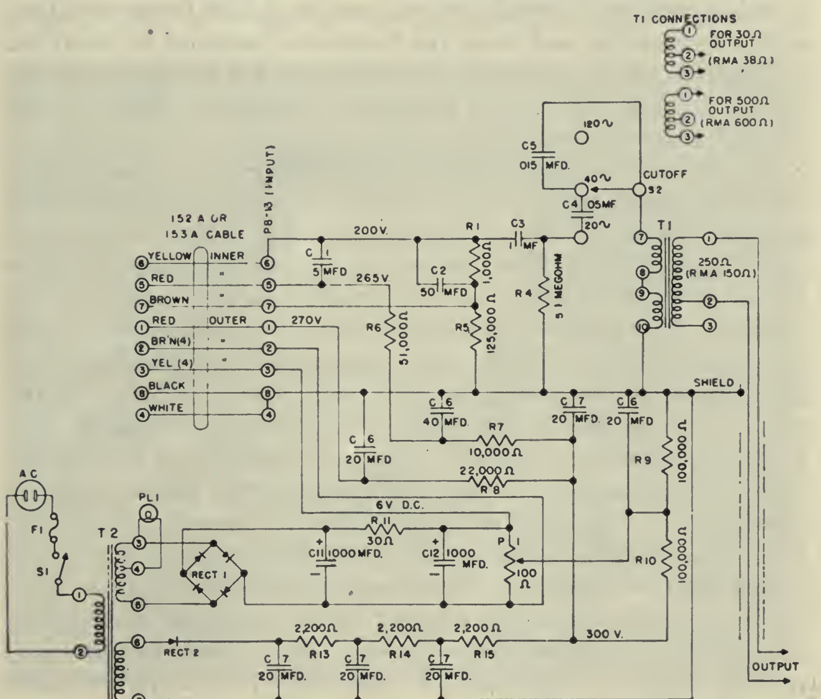

Fig. 6. P-518 power supply.

mately 30 db on a VU meter reading basis. This degree of cancellation can be achieved by virtue of the fact that since the diameter of the microphone is .6 in. the half-wavelength frequency is approximately 13,000 cycles/sec.

In this design the response of the condenser microphone extends to very low frequencies (approximately 3 db down at 10 cycles). In some cases, it is desirable to eliminate rumblings at low frequencies caused by the extraneous noise of traffic and ventilators. A switch is provided to reduce the low frequency response at a rate of 6 db per octave being down approximately 6 db at 20, 40, and 120 cycles.

USES

The small physical size of the microphone permits it to approach more closely the pattern of an ideal omnidirectional microphone at the very high frequencies. This characteristic is a material advantage where orchestra and solo channels are recorded separately and then later combined for proper balance. Directional or semi-directional microphones[9] provide less suppression at high frequencies than at low frequencies, and when the tracks are combined in recording, the high frequency content of the orchestra in the solo channel is distorted in characteristics and phase, and undesirable effects are obtained in the release product.

Use of the miniature condenser microphone for the scoring of music in motion pictures has indicated that the usual microphone placement practice can be modified. Instead of using several microphones placed near individual instruments, one miniature condenser microphone can be placed so as to obtain a good balance on the over-all orchestra. Setups have been made with all of the commonly used groups of instruments such as for main title, background scoring, small dance band routines, and full symphonic numbers. A considerable saving in time has resulted from this technique as the time required to place and balance multiple microphone setups is eliminated. The practice to date indicates that the single condenser microphone can be placed in a position directly above the conductor's head (Fig. 7). The conductor places the instruments so that the required balance is obtained. The sound mixer then has the primary function of maintaining the proper modulation on the film whereas the conductor is responsible for balance. Where more than one channel is used such as in the cases of prescoring with voice, a chestplate type of microphone has been used so as to provide the necessary isola-

tion between the orchestra and solo channels (Fig. 8). This is accomplished by placing the soloist very close to the director. Approximately 10 db of suppression on the orchestra is obtained by the use of this chestplate since the soloist is permitted to operate extremely close to the microphone without the undesirable effects usually associated with close operation (Fig. 9). Some of the advantages resulting from this technique are:

(1) The soloist is in a position which closely parallels that of concert work, and in so being hears the full volume of the orchestra and has the maximum benefit of the conductor's direction.

(2) The orchestra pickup in the solo channel has a frequency response which is equal to the orchestra channel except for volume.

(3) Re-recording for release is simplified since the phase of the orchestra in the solo channel is similar to that in the orchestra channel. This permits overlapping without undesirable effects. One of these undesirable effects results from the fact that when directional microphones are used to provide the necessary suppression between orchestra and solo channels, the suppressed frequency response is

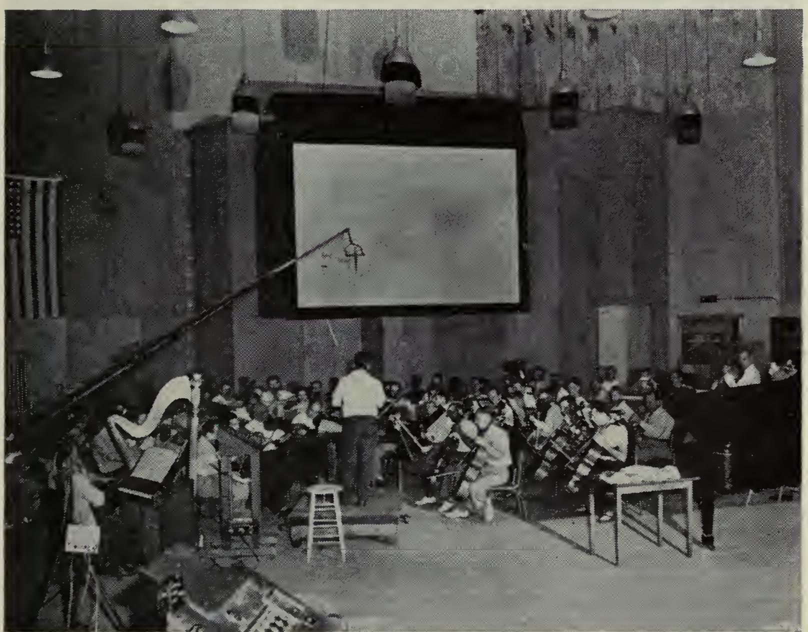

Fig. 7. Typical microphone position for recording orchestra.

such that the high frequency content is suppressed considerably less than the low frequency content. In most cases this suppression amounts up to 10 to 15 db between 1000 and 8000 cycles.

When ribbon microphones or various combinations of this principle are used, the phase shift between the particle velocity and the sound pressure causes a change in low frequency characteristics which is a function of distance from the source. At a distance of 2 ft the increase in response is approximately 2 db but at a 6-in. distance the increase is 10 db. In the case of the miniature condenser microphone, this phase shift does not occur and consequently the microphone can be used at distances extremely close to the source without producing this false bass.

In sound motion picture recording the microphone is one of the very important links in production since it involves the final quality and the various compromises that must be made by set designers, cameramen, and sound departments in order that the microphone be placed in its optimum position with a minimum of delays to the production company. Elaborate booms have been provided for both "panning" and "tilting" the microphone. Panning is required in order that fixed distances be maintained between the actor and microphone for best and uniform quality. Tilting has been required because the microphone has a varying high frequency response, depending upon the angle between the face of the diaphragm and the actor. The size of the boom has been dictated by the weight of the microphone and the mechanism required for panning and tilting. An extremely lightweight microphone reduces the demand for heavy construction and counterweighting. The elimination of tilt further reduces the complexity of controls on the boom. Use of condenser microphones in general, over a period of years, has indicated that they are less susceptible to wind disturbances than other types of microphones which have been used in motion picture production. A very small wind screen consisting of four layers of voile is provided as an accessory to the microphone. The attenuation of this material does not exceed 1 db at 10,000 cycles and provides up to 15 db suppression of wind noise.

CONCLUSIONS

This paper has stressed the improvements in sound quality and directional effects caused by the small size of the microphone. All of the features discussed contribute to produce a readily discernible

Fig. 8. 155A chestplate microphone.

Fig. 9. Relative position of soloist to conductor and orchestra.

improvement and a distinct step forward in the quality which can be obtained in sound reproduction. Experimental use over several months has indicated that under conditions varying from Carnegie Hall broadcasts to stage, motion picture, and television, obvious improvements in sound quality have been attained.

NOTE: In addition to the paper, a demonstration at the Academy Award Theatre of various types of recording, which included main title, background, combination of orchestra and solo channels, was presented. It was derived from material made by Mr. Alfred Newman of the Music Department at 20th Century-Fox Studios and the co-operation of their Sound Department.

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Supplementary Magnetic Facilities For Photographic Sound Systems

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Summary—To facilitate the introduction of magnetic recording on 35-mm film, modifications have been engineered for adapting photographic recording and reproducing systems so that they may be used alternatively for either photographic or magnetic recording. Existing transmission systems employed in photographic recording have been modified to include a bias-erase oscillator. Magnetic heads have been added to the film recorders in such a manner still to permit the use of the recorder for photographic recording. Re-recorders have been modified for magnetic only or for alternative magnetic or photographic reproduction. The existing photocell amplifier has been modified for the dual reproducing facilities.

To facilitate the introduction of synchronized magnetic recording into sound motion picture studios, it is highly desirable during the transition stage from photographic to magnetic to utilize as much as possible of the existing sound recording and reproducing equipment with a minimum of modifications. This serves the dual purpose of lessening the economic burden of the change-over and at the same time expanding the over-all recording facilities of the studios. As magnetic recording takes a firmer hold in sound motion picture production, emphasis will undoubtedly shift toward using facilities intended primarily for magnetic recording; but in the interim period the use of the dual-purpose equipment will meet with much favor.

At the time of writing this paper, the use of magnetic recording in the motion picture studios has not progressed much beyond the stage of using the medium for original recording. One of the dual equipped recorders described below may be employed for this purpose. The accepted takes are usually transferred from magnetic to photographic tracks of either the density or the area type, and the usual photographic re-recording and cutting techniques are then followed from this point. In transferring to photographic film, the "magnetic only" re-recording machine described below is preferred, and the photographic recording may, as in many small studios, be done on the dual-

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purpose recording machine. With the equipment described below either 200-mil push-pull area or density, or 100-mil single density or area may be recorded. Provision is also made for transferring the magnetic to either a direct-positive area or density track.

The design details of the components and the operating characteristics of the magnetic systems described below will not be reviewed in this paper as they have been thoroughly discussed in an earlier paper.[2] It will be noted that although the high-frequency erase facilities previously described are provided in the systems described below, the current practice in the Hollywood studios is to use a bulk 60-cycle eraser rather than the erase head mounted in the recorder. The use of low-frequency pre- and post-equalization has become well established in the industry, but the use of high-frequency pre- and post-equalization remains optional at this time.

MAGNETIC RECORDING FACILITIES

The recording and reproduction from magnetic film are being accomplished by two general methods with relation to the film path encountered in existing Western Electric film recorders of the RA-1231 type. The first consists of placing the magnetic head so that it bears on the overhanging portion of the film at the scanning drum in a manner analogous to that used in photographic reproduction. This is frequently referred to as the preferred position, since flutter and amplitude modulation are minimum at this point. The second method is that of placing the head in an open film path, such as between the recording drum and one of the compliant filter rollers, and this method is frequently referred to as loop scanning. The performance under this condition is dependent upon several design factors, but in general is not as good as the drum position with respect to high-frequency flutter rates. Typical flutter values for the drum position in either recording or reproduction are .06% to .08% total flutter, most of which is found in the higher flutter rates with low-rate components very small, the over-all performance being comparable to photographic recording. Flutter values for the loop position are substantially the same at all lower flutter rates, but are somewhat greater at the higher rates, particularly at the 96-cycle sprocket hole rate. The amount is somewhat dependent upon the relationship between sprocket pitch and that of the film, but for normal operating conditions is well below the accepted threshold limit for perceptibility.[2] It has been shown[3] that the fundamental

relationship between flutter rate and its minimum perceptibility will permit much larger values at high rates. For example, flutter at 96-cycle rate may be nearly 10 times that at rates between 5 and 10 cycles for equivalent perceptibility.

The addition of magnetic recording and monitoring facilities to the RA-1231 film recorder is shown by Fig. 1. The magnetic head at the drum position is shown as the light-colored circular object located in front of the recording drum and bearing upon the overhanging edge of the film which has the magnetic coating on the inside surface. An identical magnetic head used for monitoring may be seen at the right just above the film and located in the film loop between the recording drum and the lower right-hand filter roller. Both heads are adjustable for azimuth and track position and the recording head mounting is pivoted so that it is pressed against the film with a controlled pressure at all times to compensate automatically for factors such as film curl. This arrangement maintains proper contact at all times between the surfaces of the head and the film coating, and its motion is well damped to maintain stability and damp out small transient motions such as those produced by a splice passing the head. The recording-head mounting is also provided with a device for retracting the head and holding it away from the film to prevent contact during photographic recording, particularly in the case where the modulator is moved toward the front of the machine to record on the outside edge of the film for producing direct-positive sound tracks without the necessity of reversing the direction of motion of the film in the recorder.

Good contact is maintained between the film and the monitor head by virtue of the uniform and constant tension in the film path between the two sprockets.

A magnetic erase head is also available for application to this recorder, although it is not shown in Fig. 1. When required, this head is mounted in a manner similar to the monitor head and is located to the right of the film in the path between the left-hand sprocket and the left-hand filter roller so that the film may be erased ahead of the recording point.

For magnetic recording, the film magazine is replaced by a reel adapter mounted in the same manner as a magazine. It permits the use of either the 10-in. sheet-metal reel having a 2-in. hub, or the preferred reel having an 11-in. diameter with a 4-in. hub. All magnetic conversion parts are available in kit form and may be applied

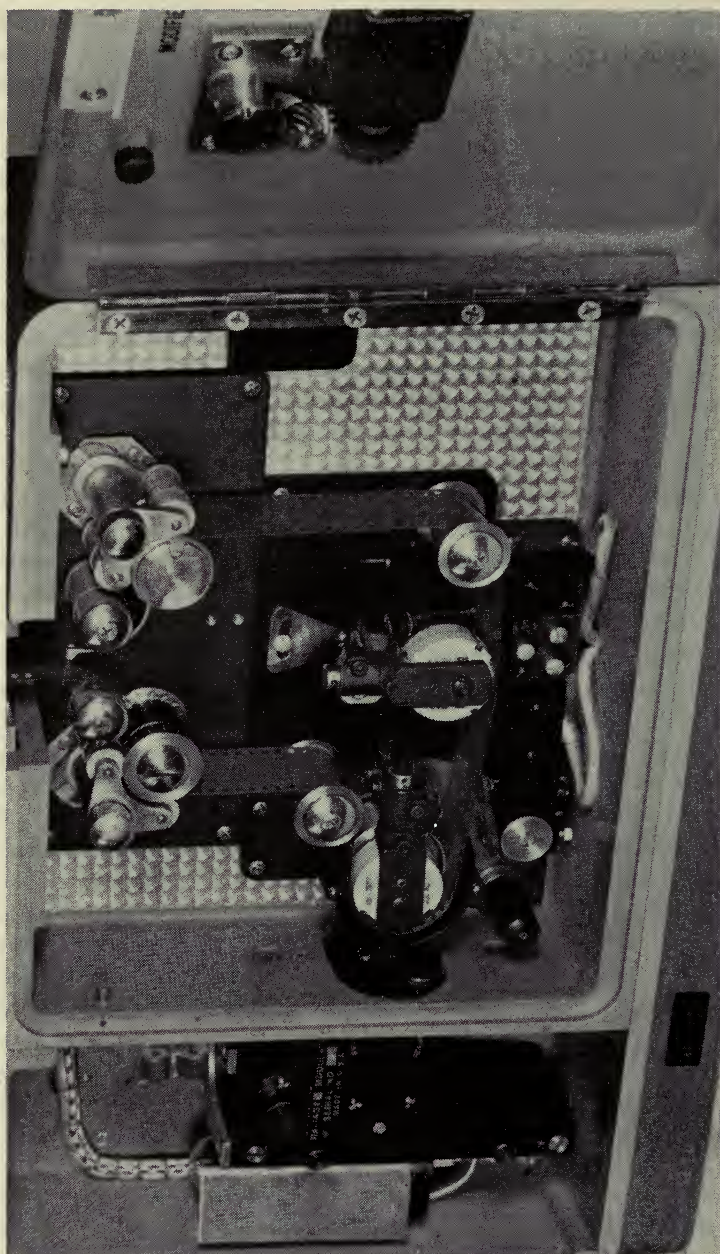

Fig. 1. Front view of RA-1231 Recorder equipped for magnetic recording and monitoring in conjunction with negative or direct-positive, variable-area photographic recording.

to any of the Western Electric RA-1231 type of film recorders without impairing in any way their usefulness as photographic recorders. Thus it is possible to have alternative magnetic variable-density recording or alternative magnetic and variable-area recording on any of these film recorders.

MAGNETIC REPRODUCING FACILITIES

Magnetic reproduction may be roughly divided into three classifications: immediate playback following recording (which for convenience should be done on the same machine making the recording), magnetic re-recording operations requiring adaptation of existing re-recording machines and magnetic reproduction in theater-type reproducers for use in the studio review room.

The immediate playback is available by using the monitor facility of the RA-1231 Recorders as described above, or in certain cases where high-quality performance is required, the recording head may be electrically reconnected and used for reproduction.

For the re-recording of magnetic tracks, two modifications have been made available for the RA-1251 type of re-recording machines recently described,[4] in which both the drum and loop scanning positions may be utilized. The first of these uses the preferred drum position as shown by Fig. 2, which is a close-up of the center section of the machine. All of the facilities for photographic reproduction are removed and a magnetic head is placed within the film drum contacting the over-hanging position of the film in the same manner as in the recorder. The magnetic head is pivoted and mounted in the same manner to insure adequate contact between the head and film under all conditions of operation. Similar adjustments for head orientation, azimuth, track position and pressure are provided. The only changes required in the film path or machine facilities are those directly related circuit functions pertaining to the equipment removed and the transmission facilities which are described later. The second modification consisting of placing the magnetic head in the loop position is shown in Fig. 3. This permits the retention of the standard photographic reproducing facilities so that the machine is available for either magnetic or photographic operation. The magnetic head is contained within the small rectangular unit mounted between the impedance drum and lower filter roller as shown by Fig. 3. This unit also contains a fixed idler roller so that for photographic

operation, the film is threaded over this roller instead of through the slot as shown in the figure. The change in film-path angle between these two methods of threading also serves to compensate for the added friction of the film over the magnetic head so that the two filter rollers operate in substantially the same positions with both types of film. This modification requires little change in the basic machine, except for the addition of the head assembly as shown

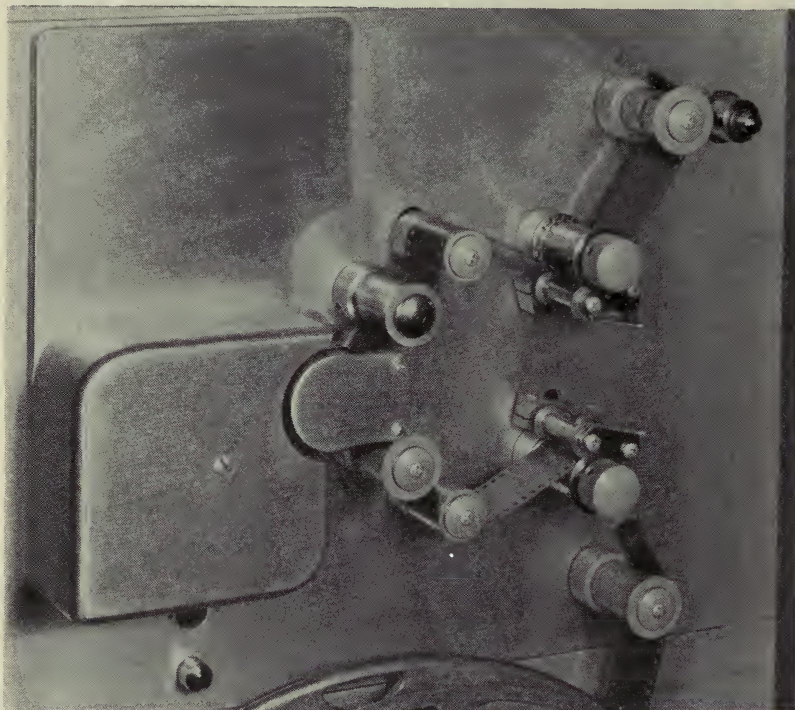

Fig. 2. Close-up of RA-1251-B Re-recorder equipped for magnetic reproducing (or recording) at the drum position for optimum flutter performance.

which replaces a fixed roller. The magnetic head is terminated in a plug on the rear of the removable mechanism section and provision has been made so that the photocell amplifier may be utilized as a magnetic head amplifier to provide an over-all flat frequency response, as described later.

Both of these modifications are available in kit form for application

to existing equipment, and in the event that either of these magnetic modifications is desired for recording purposes, an erase head unit has been designed to be mounted in much the same manner as described for the recorder. Figure 3 shows this erase head assembly mounted in the film loop between the upper sprocket and the first filter roller in combination with the photographic and magnetic

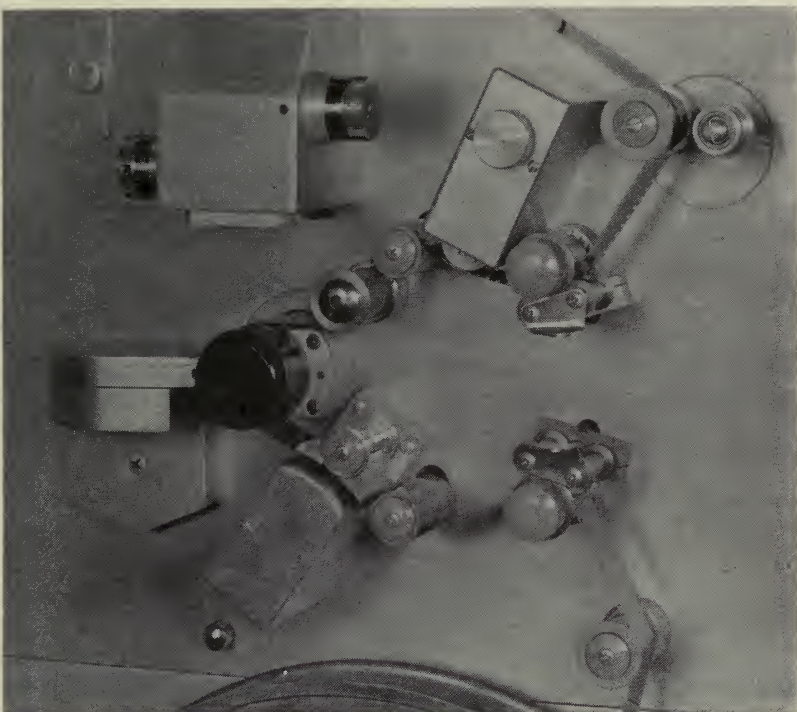

Fig. 3. Close-up of RA-1251-B Re-recorder equipped for both photographic and magnetic reproduction and erasure, with the film shown threaded for magnetic operation passing over the magnetic head under the cover located below and to the right of the impedance drum.

modification. A knob on this unit retracts the head from contact with the film during photographic operation to avoid film damage, but does not in any way affect the other performance characteristics of the film pulling mechanism. A similar assembly is available for the other modification employing drum scanning, but it is of course located on the other side of the film, since the coating is on the other

side in this type of operation. In this case the magnetic head is fixed, without the retractable feature, since photographic film is not encountered.

Review Room Facilities

A new theater reproducer, which is primarily intended for wide-track photographic reproduction in studio review rooms, has been described recently.[5] Figure 2 of that previous paper shows the reproducer equipped with a magnetic head located in the loop position directly below the scanning drum. Since this machine is designed for both photographic and magnetic operation, the magnetic head is also retractable so that it does not contact photographic film, to avoid scratching. The flutter performance is essentially the same for photographic and magnetic except for the higher values at higher rates as discussed above.

Transmission Facilities

The transmission facilities of both the portable (300 type)[6] and deluxe (400 type)[7] recording systems have been adapted for use with the magnetic recording machines described above. As in the case of the recorders the modifications have been made in such a way that the photographic facilities are retained and change-over between the two types of operation is readily made. The modification parts have also been provided in kit form to permit conversion in the field.

"300 Type" Portable System

Although compactness was one of the primary features of the "300" system design, it has been possible to add the magnetic and magnetic-photographic change-over facilities without adding to the number of component units or increasing the over-all size of any of the units. All changes have been confined to the recorder, including the photocell monitor assembly mounted within it, and the main transmission unit. The adaptation has been applied to both the variable-density and the variable-area versions of these units.

The modifications of the main transmission unit for alternative variable-density photographic or magnetic recording are described below.

High-Frequency Bias. A high-frequency bias signal superimposed on the speech signal is normally used in high-quality magnetic recording systems to minimize distortion caused by the nonlinear

characteristics of the magnetic medium.[1] In this system it has been possible, by relatively minor circuit modifications, to utilize the 30-kc carrier frequency oscillator associated with the noise-reduction circuit as a source of high-frequency bias signal.

In the modification, the signal frequency is changed from 30 to 60 kc to obtain a greater spread between speech and carrier for minimizing intermodulation components. This change does not affect the performance when operating as a noise-reduction circuit.

To prevent modulation of the carrier by the speech signal (as is done in normal noise-reduction operation) the oscillator is disconnected from the rectified audio signal under magnetic operation.

In the noise-reduction output circuit, the output transformer is replaced with one of equivalent performance except for an added 600-ohm output winding to operate into the recording magnetic head. Also a means of metering the high-frequency signal using the D-C Noise Reduction Bias Meter is provided. The oscillator circuit is capable of supplying over 30 milliamperes to the output circuit, which is more than ample for optimum recording conditions.

Frequency-Response Characteristic. The low-pass filter normally used in 16-mm recording has been modified to provide a relatively sharp cutoff at 9,000 cycles per sec for magnetic recording. This prevents the high-frequency bias from feeding back into the amplifier output circuit where it would affect the volume indicator or meter reading and possibly introduce intermodulation components.

Power Supply to Monitor Amplifier. The heater supply to the associated monitor amplifier in the recorder has been connected to the 12-v d-c line instead of the 6.3-v a-c line. This retains the monitor system hum level at a satisfactorily low level, whereas it would otherwise be emphasized under magnetic operation due to the 6 db per octave slope of the reproducing system frequency-response characteristic. A ballast lamp is added for current regulation under the conditions of variable alternating-current supply voltage and variable current drain to the recorder lamp.

The variable-area version of the main transmission unit has not previously been described in the JOURNAL. It differs from the variable-density unit principally in that peak-chopping has been provided, the light-valve equalizer has been modified to provide characteristics complementary to those of the variable-area light valves and the noise-reduction filter has been adjusted for optimum variable-area attack and release times.

The magnetic facilities are essentially the same for the variable-density and variable-area versions of the main transmission unit, the peak-chopper circuit in the latter version being disabled when recording magnetically in order to utilize fully the gradual overload characteristic of the magnetic medium.

By furnishing the modification parts in the form of wired subassemblies, the change-over can be made economically in the field with a minimum disturbance to the original components and wiring.

Monitor Amplifier in Recorder. Alternative magnetic and photographic film monitoring is accomplished by installing in the rear compartment of the recorder a new monitor amplifier. This amplifier has a photocell input for photographic operation from the modulated light beam and a low-impedance transformer input for operation from the magnetic monitoring head. An internal transfer switch connects the desired input circuit and also selects between two feed-back circuits around the first two stages; one provides a flat characteristic for photographic and the other a 6 db per octave slope for magnetic monitoring.

With magnetic operation a signal-to-noise ratio better than 50 db can be obtained from an over-all flat reproducing system. This value is considered adequate for portable production applications and therefore pre- and post-equalization has not been added.

"400 Type" DeLuxe Recording System

In the deluxe, "400," photographic recording system, such as used in major studios for production, scoring and re-recording, the various electronic components are separately packaged units adaptable for mounting in standard equipment cabinets or custom-built consoles. These transmission assemblies normally operate in conjunction with the deluxe variable-density or variable-area recorder and the automatic recorder control cabinet.

Modification of these systems for alternative magnetic and photographic operation has been accomplished by providing modifications of two of the existing system components and adding two new components as described below.

Photocell Monitor Amplifier. This amplifier, mounted in the recorder control unit, normally operates from a photocell mesh circuit and provides a flat over-all frequency response for monitoring at an output level of approximately 0 dbm. By adding an input transformer, a magnetic reproducing characteristic of 6 db per octave

slope and a switch for transferring between the two circuit conditions, the amplifier can be made to function for both types of recording. The output attenuator can be adjusted as required to provide direct and film-monitor balance in both cases. This modified amplifier is also used in the modified re-recorders described above to provide a flat over-all response characteristic when re-recording or reproducing from magnetic film.

Recorder Control. A feature of the standard photographic recorder control unit is the provision for automatic switching, in proper time sequence, of the recorder speech input, noise-reduction bias, recorder lamp, motor and other miscellaneous circuits at the beginning and end of each take from a single start-stop push button. This is accomplished by a positively driven multiple-cam assembly operating on a series of individually adjustable micro-switches. Protective interlocking features are also included.

In the magnetic modification both the manual and automatic operating features are retained for both types of operation. By operating two transfer switches within the unit the following circuit changes are made:

(a) Speech Off-On switch is transferred from the light valve to the magnetic head circuit.

(b) Power to the light meter and noise reduction unit is transferred to the bias-erase oscillator which is one of the added units described below.

(c) The meter used for measuring exposure is transferred to measure bias and erase current.

In addition, several items are added on completely wired subassemblies including bias and erase controls, high-frequency suppression filter (to prevent the bias current from affecting the volume indicator reading) and a high-frequency post-equalizer.

The latter is used in the monitor circuit to complement a high-frequency pre-equalizer added in the recording circuit as described later.

Bias-Erase Oscillator. This new unit is added as a part of the system modification. It is a single-stage, push-pull oscillator employing two 6L6 Vacuum Tubes. In the output circuit a tuned filter provides an output signal having approximately 0.1% even harmonics. This prevents the introduction of objectionable noise and distortion due to an unsymmetrical bias or erase signal. Since the output control potentiometer is in the common cathode circuit, the

total plate drain varies with the signal level. By this means the plate drain is reduced from approximately 75 milliamperes for bias plus erase, to 30 milliamperes for bias only. The oscillator is capable of providing a maximum load current of 275 milliamperes at an output voltage of approximately 65 volts.

Pre-Equalizers and Recording Circuit. The low-frequency pre-equalizer has an 8-db peak at 60 cycles per sec. The high-frequency pre-equalizer is the conventional one used for many years in many Hollywood studios which has a 12-db rise at the high frequencies. The use of these two equalizers increases the effective signal-to-noise from approximately 50 db to approximately 58 db. Complementary low-frequency post-equalization in the monitoring circuit is obtained by properly selecting the low-frequency shelf-point for the 6 db per octave reproducing equalizer. A high-frequency post-equalizer is provided in the monitor circuit of the recorder control and mixer units.

A general purpose amplifier such as is used as a mixer and booster amplifier is provided to operate into the magnetic recorder head. This is preferable to utilizing the standard limiting amplifier because of its lower noise level and more gradual overload characteristic. However, the limiting amplifier is retained to operate the volume indicator and direct monitor circuits in the normal fashion, which greatly simplifies the circuit changes required when transferring between the two types of operation. For magnetic operation the limiting action is disabled and the peak-chopping level is set to its maximum value in order that it will affect only the occasional, short-duration overloaded peaks.

The added components, consisting of bias-erase oscillator, low- and high-frequency pre-equalizers and magnetic recording amplifier, can either be mounted in the console or cabinet of a particular system or may be assembled in a small portable cabinet with patching facilities for connecting to any system as required.

Since the modifications made in the standard system include transfer of power from the light meter and noise-reduction unit, no additional power unit is required when connecting the special magnetic facilities.

The magnetic modification facilities described herein have made available to the industry an immediate and economical means of utilizing existing studio equipment for both experimental and production magnetic recording.

Experimental investigations will allow the studios to familiarize themselves with this new medium and to assess its technical and economic value as applied to their particular production requirements.

Production experience with this modified equipment will also form the basis for the establishment of design requirements for the equipment which will eventually be made available for the magnetic recording of sound for motion pictures without the encumbrances of photographic recording facilities.

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Sprocketless Synchronous Magnetic Tape

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Summary—**Advantages inherent in the normally thin, narrow magnetic tape may be realized with a new method of obtaining true synchronism with film for motion pictures. Adaptability of the system to dubbing and post-synchronization is described. For television sound, it offers wide-frequency response and long playing time.**

ALTHOUGH OFTEN THE BANE OF HIS EXISTENCE, sprocket holes have nevertheless been a boon to the motion picture engineer since Edison's day. All motion picture equipment has been built around the sprocket hole; and then, of necessity, very thorough effort has been made to eliminate sprocket-hole flutter. Quite naturally, therefore, when magnetic recording showed its great possibilities, the first thought was to coat normal sprocket film base with magnetic coating, substitute magnetic heads for light valves and phototubes and carry on largely with the normal equipment. A very complete discussion of this approach has been given in the JOURNAL.[1] There are also several other JOURNAL articles of interest.[2] Concentrated efforts have also been made to place a narrow strip of magnetic coating on normal photographic stock so that the sound could be recorded on this strip, while the rest of the film carried the normal picture. This appears to be the ultimate system for prints.

Narrow magnetic tape has come to the fore. It is only .002 in. thick and has definitely established its position in sound reproduction. Its very thinness may hold some of the secret of its success; and, of course, the quarter-inch width makes for lighter and more compact reels. The application of this thin tape to synchronized operation has been so well developed that it is now successful in a practical manner. Also, during this development other advantages of this method of operation have been discovered, and these will be described.

This new system is independent of slippage and possible stretch of the sprocketless tape; these exist and perhaps always will. Furthermore, even if the tape drive were perfect, that of the motion picture film is not; it depends on the frequency of the power driving the cam-

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era motor. This may vary from instant to instant and day to day. What is really essential is not absolute speed regulation, but relative uniformity of speed between tape and film. As some form of registered control is absolutely essential, this system without actual perforations uses what might be termed "magnetic sprocket holes." They actually are magnetic recording of the pulses of the power driving the camera at the same time that the sound is being made. Normally this is 60-cycle power, so on the tape this power frequency is recorded simultaneously with the sound that is to accompany the pictures being shot. This power-frequency recording will then be used as a control to keep projector and tape in step for subsequent reproduction.

One immediate advantage that this method of registering control gives is that it is unnecessary to work with any kind of speed control in the tape recording other than the normally smooth advance of the tape accomplished with the aid of the synchronous motor-driven capstan of the tape machine. A good recording is assured with normally engineered tape equipment.

The sound recording on the tape is accomplished with normal magnetic heads, shown as the center three of the five of Fig. 1. These three are the "Erase" to clear the tape of any previous recording, then the "Record" which puts down the normal sound recording, and finally the "Playback" which gives the immediate playback to monitor the recording and then the final playback for recording. It is to be noted that all of these heads are magnetic toroids with the gaps in the toroids extending vertically across the tape. As the magnetism varies in these heads the tape will be correspondingly magnetized longitudinally, *i.e.*, in the direction of travel of the tape.

Now come the two control heads. The one on the left, which the tape traveling to the right first hits, is the "Playback Synchronizer." The one on the right is the "Record Synchronizer." It will be noted that, although these are also toroids, they are oriented at right angles to the other three; and this places their gaps in line with the tape movement. The magnetic effect in the tape with which they are concerned will therefore be up and down or vertical to the tape movement. This reorientation makes it possible to put the control signals on the tape without interfering with the normal sound recording, for two reasons: first, the control signal is made in a very narrow band in the center of the tape; and second, with its magnetism at right angles to the normal sound magnetism, the effect is definitely minimized. Actually it is possible to adjust the relative angles of the heads to ob-

tain this minimum; and normal sound level will be well above 50 db stronger than the remanent control signal which is picked up by the normal "Playback" head.

A large portion of motion picture work is made "double system," one equipment for the picture, the other for the sound; so here there is virtually no additional equipment necessary for tape sound instead of film sound. As a matter of fact, the tape sound equipment is lighter

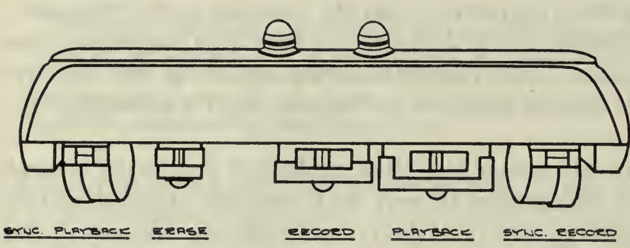


Fig. 1. Arrangement of magnetic heads.

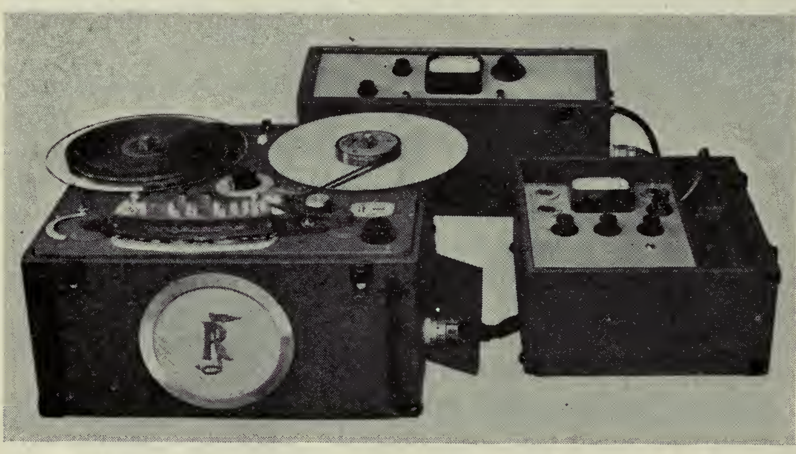


Fig. 2. Field unit, with recorder and microphone pre-amplifier.

than most sound film equipment. Furthermore, and here is the next big advantage of the tape, enough for an hour's steady recording can be readily accommodated in the tape reel.

On location the sound man sets up his portable equipment (see Fig. 2) about twenty-five feet away from the camera. A cable goes to the pre-amplifiers from which three microphones may be controlled with high-level mixing, earphones and VU meter. A preliminary run is made on the sound without the camera, and the director is able to call for a playback immediately to judge the quality and placement. After

this first test, it is usual for the sound man to run the tape back to the start and then be ready for the next, or real, take. This will erase what has been previously recorded. But after this first test, it is never wise or necessary to go back and erase any subsequent takes. That they are "Out-Takes" is just noted on the log, and the next take proceeds. It is of course wise to have blind track made on the scene, to have the normal background noises for subsequent splices which will then give good uniformity with the normal background noise. Also, these "Out-Takes" can often save the day by giving replacement material to substitute for some extraneous noise which may have gotten into what would otherwise be a good take. It is well to save everything once recording starts.

Incidentally, it is interesting to note that this synchronizing technique lends itself to all magnetic tape recorders of this variety. To adapt an instrument for this work, a synchronizing record head and associated circuits for recording the sixty cycles are simply added to the recorder. The recorder operates in its normal way otherwise.

Editing and splicing tape are relatively simple; there is no blooping problem. Also no attention need be paid the "magnetic sprocket holes." The greatest possible error in splicing them would be one-half a cycle which is less than one-quarter of a frame. The law of averages produces advances half the time and delays the rest, and to date no noticeable discrepancy has been discovered in an accumulated frame error from this source. Two continuous music sequences may be spliced without any noticeable bloop in the sound, although it is better for cadence values to make splices in silent portions.

When the takes have been assembled, they are then ready for dubbing to sound negative film. It is, naturally, best to run through the sequences to furnish the sound engineer, who is to do the dubbing to film, a chance to determine his dynamic values and frequency equalization before the film is exposed. The series of sequences is then run through as quickly as the series of film reels may be changed. The frequency range available from the tape is from 40 to 15,000 cycles, so that the dubbing engineer has a great chance to get the maximum out of the recording onto the film. Some very successful full orchestral selections have been made by this process.

To synchronize the tape to the film recorder, two methods are available. The first is to take the control signal recordings from the tape, amplify them sufficiently to control a thyratron inverter, shown in Fig. 3. This inverter gives 250 watts at the exact frequency of the control signals on the running tape. If this energy is delivered to the

film recorder, the sprocket holes of the film in this recorder will be advanced in strict accord with the magnetic control on the tape, so that perfect synchronism results.

Another method is to compare the control signals coming off the tape with the 60-cycle power then being used to drive the film recorder. This comparison may be made automatically in a bridge ar-

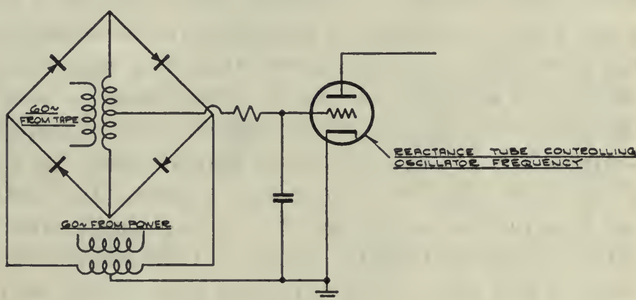
Fig. 3. Thyratron inverter.

rangement operating on a vacuum reactance tube as given in Fig. 4. This reactance tube in turn controls the frequency of an oscillator tube set normally for 60 cycles. This oscillator tube then drives the thyratron inverter previously mentioned, but which is now used to drive the synchronous motor on the tape machine. If the signal on the tape happens to be exactly in step with the power frequency at

the moment, the bridge is balanced and the reactance tube does nothing to the oscillator. But if the tape gets ahead so that the control frequency on the tape is ahead of the power source, then the bridge becomes unbalanced to the point of slowing down the tape advance, until the control signals on the tape are exactly in step with the power frequency. The tape is moved ahead if it gets behind by the reverse process of course. It is necessary to make this control quite slow so that it will cause no "wow" in the sound. It has been found that if this correction is at a rate of less than one cycle in two seconds, no speed variation can be heard.

Post-synchronizing offers a very interesting application of tape for the sound. In this operation, the sound is recorded on tape with the best possible attention to microphone placement. For this work, the control signal is not put on the tape at this time as the cameras are not

Fig. 4.



in action. Instead, the control signal is put on during the subsequent playback amplified to a loudspeaker to which the actors are performing for the cameras. So the control "Synchronizing Record" head is energized at the time that the cameras are likewise running in step with the 60-cycle power then in use. Thus, the control signal gets on the tape in step with the film for the pantomimed action. If long shots and close-ups are to be made from the same sound playback at different times, the synchronizing control signal is put on the tape during the long and usually continuous shot. Then the automatic control is used for the short close-ups to make the tape run in synchronism with the cameras then being used.

Tape has a third interesting advantage. With its flexibility, the tape may be made to accommodate or correct what often are slight errors in the timing of the actors playing to sound. For example, it was found that a very important orchestra always had a tendency to speed up over its first rendition of a given piece when it was perhaps

straining a bit to keep in strict step with the sound; therefore, after several attempts, the engineer simply speeded up the tape very slightly on the playback for camera action and the net result was perfect.

This may be carried a step further in a method that has already been tested, namely, a good musician controls the speed of the tape on playback and keeps the tape sound in step with that of the orchestra. This relieves the orchestra and the conductor of any strain in trying to do a double job themselves. So the orchestra and the conductor carry on in their normal manner after once having got the start from the loudspeaker playback, and the musician at the controls does the rest.

Now, as for dubbing: in this case the picture is made first and the sound subsequently recorded from the actors who are following the film pictures as they are projected. Tape now shows a fourth advantage. First, any number of tries may be made without wasting recording stock—and everyone knows that it is only with extreme difficulty that a perfect job can be accomplished, no matter how many the tries. But with tape, discrepancies may be corrected. For this purpose, loops of tape and picture film are made. As good as possible a take of the sound with the picture is made. The control signal is on the tape for this sound, and it is in step, supposedly with the film. But at certain portions the sound is a trifle late or early. (It is much worse if it is early. Distance gives a customary lag.) So the tape should be advanced or retarded to correspond. As is noted in Fig. 1, the "Synchronizing Playback" head comes first in the head assembly. So with the automatic control on, this head will see to it that the tape moves forward in step with the film. An indicator on the front of the Automatic Synchronizer control indicates Frame Advance or Retard from Zero accord, as shown in Fig. 5. But the automatic control may be thrown off when desired, and manual adjustment be substituted. Then the tape may be moved forward or back an appropriate number of frames. The operator tries this in dry runs until he makes the two agree very nicely, then he registers the new control once and for all. To do this, he goes through the same manual control, but turns on just the "Synchronizing Record" head.

Unpremeditatedly, it has turned out that this construction of "Synchronizing Record" head and the type of control signal put down on the tape may be overridden very completely by a second application of energy to this same head. So, in effect, a previous control signal may be completely replaced with a new one when desired. There-

fore, as the operator advances or retards the tape by frames, the new control signal is registered with the energy turned into this head, and thereafter automatically controlled playback will keep to this new step. Furthermore, if slight additional correction is necessary the process may be repeated.

Just one precaution: it is necessary when making such manual changes to be sure to come back to zero frame deviation at the end of the tape loop, so that the next run-through of the loop will start with the film. Also, another advantage of the positioning of the "Synchronizing Record" in the succession of heads gives the operator his reaction time to make the frame change slightly after he has observed the necessity for it. The separation between these end heads is 7½

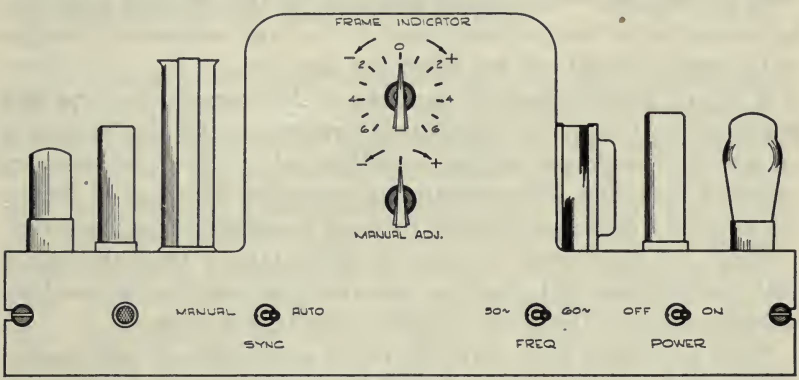


Fig. 5. Manual or automatic control unit for synchronous tape drive.

in., so at 15 in. a second, the normal tape speed, he has half a second to make the change indicated. The net result is that he can do it very smoothly.

Sound for television gives tape a fifth advantage. A double system of operation may be used for simultaneous transmission of pictures from film and sound from tape. Tape with its top frequency capability of 15,000 cycles offers full range to the FM sound transmission of television. Furthermore, it is no problem at all to run a straight half-hour of sound from tape, synchronized with the film.

The methods of starting tape and film together are to be noted. One method is to have normal start marks on tape and film, to place the film in the projector at this start mark on the film and to use a strip of metal foil stuck to the back of the tape at the start mark on the tape to start the film projector. The tape is started with a short leader ahead of this metal foil. Then when the tape is up to speed, along

comes this foil strip which makes a brief connection with a contact on the tape machine, and this closes a relay which starts the film projector. The time that it takes the projector to come up to speed is fairly regular, and it can be calibrated once and for all so that repeated starts may be made by this process without difficulty.

Another similar method for making the start also uses a leader on the tape ahead of the start mark. This leader has control signals on it for all but the last inch of the leader ahead of the start mark. A sensitive relay in the amplified output of the control signal operates on the control signals, and then when the momentary halt in them comes along, the sensitive relay drops back on its back contacts and the projector relay is set for this condition to get its start, so that then off both go together. Subsequent operation of the sensitive relay will have no effect on the projector relay, so that any momentary changes in the control signal will not affect the operation.

If at any time it becomes apparent to the operator that the tape needs to be advanced or retarded with respect to the film because of an error in threading or editing, something which he can become very expert in observing, the automatic synchronizing lock may be thrown off, and the framing be adjusted by hand smoothly during operation.

Shows are now being televised in which tape is used alternately with live program, with excellent uniformity between the two methods of presentation. This makes feasible a new type of program.

Tape is making real advances in its application to the motion picture field. Some of these have been most unexpected, and there is every reason to believe that as more people become acquainted with its potentialities, other uses will develop.

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A New $f/1.5$ Lens For Professional 16-Mm Projectors

By W. E. SCHADE

Eastman Kodak Co., Rochester, N.Y.

Summary—To meet the growing demand for improved high-aperture 16-mm projection lenses, the Eastman Kodak Co. has announced a new series of $f/1.5$ lenses primarily intended for professional projectors. The lens is fundamentally of the Petzval type with field flattener. The resolving power, contrast and back focus clearance are substantially greater than in present designs. The paper includes a historical outline of the development of lenses of this type, showing the progressive improvements in aberration correction that have been attained in recent years.

One hundred and nine years ago, one year after Louis Jacques Mande Daguerre (1787–1851) had announced the first practical process of photography, the daguerreotype, another important contribution to the new science, was introduced. Joseph Petzval (1807–1891), a professor of higher mathematics at the University of Vienna who had undertaken the design of a new lens for photographic purposes, was ready to present the results of his computations, the famous "Portrait Lens" (Fig. 1). The performance of the new lens, because of its excellent correction of spherical aberration and coma in combination with the unusually high aperture of $f/3.4$, was of such outstanding quality that it became the most prominent lens in the studios of all photographers. Besides the photographers, other groups, such as the manufacturers of optical instruments, as well as the contemporary opticians showed great interest in the new lens. The theoretical opticians of that time were impressed mainly by Petzval's new methods of lens design. His theories concerning aberrations, astigmatism and curvature of field were indeed new, and his theorem, the well-known "Petzval Sum" $\left(\frac{1}{R_p} = -\sum\frac{\phi}{n}\right)^*$ has been

* R_p is the radius of field curvature near the axis of the optical system when it is free from astigmatism; and

ϕ is the surface power $\left(\frac{n' - n}{r}\right)$ where n' and n are the indices of refraction and r the radius of curvature.

Presented: October 14, 1949, at the SMPE Convention in Hollywood.

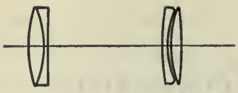


Fig. 1. Original Petzval Portrait Lens (1840)

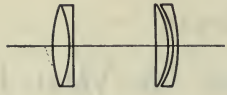


Fig. 2. Dallmeyer (1866) Zincke-Sommer (1870)

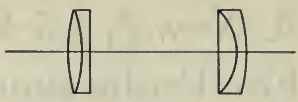


Fig. 3. Voigtländer (1878)

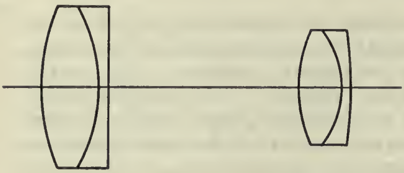


Fig. 4. Kodak Projection Lens $f/1.6$ (1935)

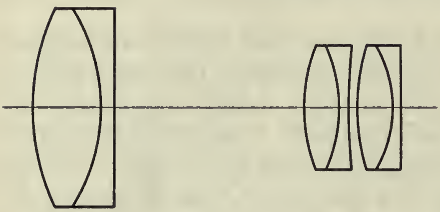


Fig. 5. Kodak Projection Lens $f/1.4$ (1939)

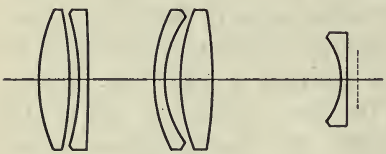


Fig. 6. M. V. Rohr (Zeiss) (1911)

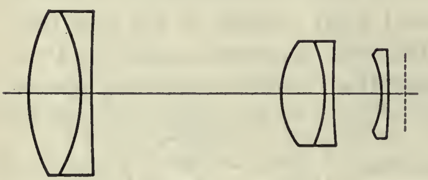


Fig. 7. Kodak Projection Ektanon $f/1.6$ (1938)

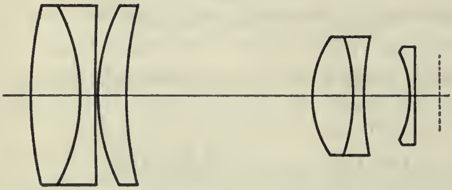
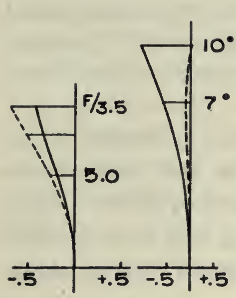


Fig. 8. Kodak Projection Ektar $f/1.5$ (1949)



(a) (b)

Fig. 3

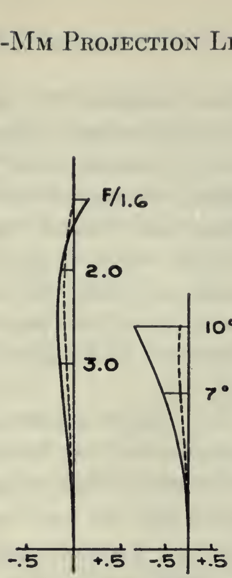


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Fig. 4

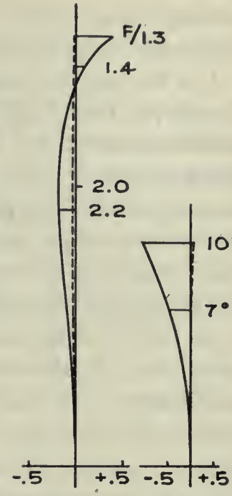

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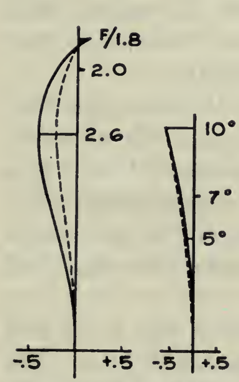
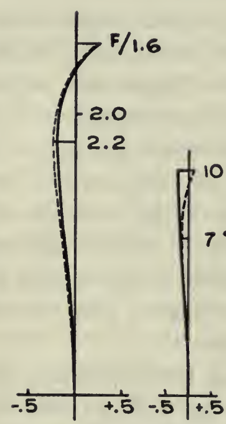
Fig. 5



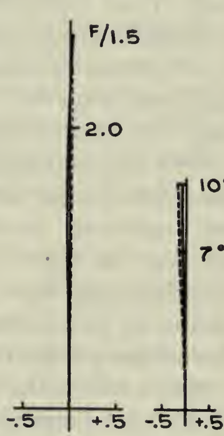
(a) (b)

Fig. 6



(a) (b)

Fig. 7



(a) (b)

Fig. 8

Curves of spherical aberration, focal length differences and field curvatures for the lenses shown in Figs. 3 to 8 on the opposite page.

an important "tool" to lens designers ever since. It has been said that with Petzval the era of serious lens design had begun.

For twenty-five years the "Portrait Lens" was without any rival. Finally, in 1866 J. H. Dallmeyer[1] entered the competitive field with a modification of the Petzval lens, which was followed in 1870 by Zincke-Sommer with a similar design (Fig. 2). The modifications of the original Petzval lens consisted mainly in the reversed arrangement of the two single lenses composing the rear component. However, both designers were successful in increasing the relative apertures to $f/3$ and $f/2.37$ respectively.

In 1878 Voigtländer[2] was granted a German and a British patent based on a further modification of the Dallmeyer and Zincke-Sommer designs. He had succeeded in eliminating the airspace in the second component, and claimed that his lens, having only four air-glass surfaces against six in the other portrait lenses, would transmit more light and therefore render clearer images (Fig. 3).

The spherical aberration (full line) and the focal length difference (dotted line) of this Voigtländer $f/3.5$ lens for a focal length of 100 mm is indicated in Fig. 3a. The under-corrected spherical aberration, however, could be easily reduced and would then be closely comparable to that of the original Petzval lens.

The field curvatures for a focal length of 100 mm are shown in Fig. 3b. The meridional field (dotted line) is flat, but the sagittal field (full line) is curved.* The longitudinal separation between the two fields, the astigmatism, increases rapidly with obliquity.

With the approach of cinematography, it was this lens type that was selected to be used as a projection lens for 35-mm, 16-mm and 8-mm projection. Its merits of high contrast and excellent definition in and near the center, combined with simplicity and reasonable cost of manufacturing, have tempted many optical designers[3] to increase its usefulness with respect to higher relative apertures with improved aberrations and field curvature.

Such a lens is the Kodak Projection lens shown in Fig. 4. It is of the Petzval–Voigtländer type with a relative aperture of $f/1.6$. The spherical aberration (Fig. 4a) is small and the meridional field is flat (Fig. 4b). The performance of this lens is satisfactory. A lens of 2-in.

* The meridional field is determined by oblique rays which enter the optical system in the plane of the drawing.

The sagittal field is determined by oblique rays entering the optical system in a plane perpendicular to the plane of the drawing.

focal length, which is the standard for 16-mm projectors, resolves[4] about 100 lines/mm in the center, gradually falling off to about 20 lines/mm in the corner of the 16-mm frame, at a semi-angle of $6\frac{1}{2}°$.

Another recent modification[5] is the Kodak Projection lens $f/1.4$. To attain a relative aperture higher than $f/1.6$ the designer divided the second component into two, and was thus able to increase the relative aperture to as high as $f/1.3$. The spherical aberration, as shown in Fig. 5a, for an aperture of $f/1.4$ is small and the field characteristics are the same as those of the examples, Figs. 3 and 4. The lens was especially designed to be used in focal lengths longer than 2 in. A lens of 3-in. focal length will resolve 90 lines/mm in the center and 40 lines/mm in the corner of the 16-mm frame. The projected image is of high contrast and also free from lateral color and distortion.

THE FIELD FLATTENER

As early as 1874, the British astronomer Charles Piazzi Smyth (1819–1900) invented an ingenious device for flattening the curved field of the Petzval portrait lens.[6] He placed a negative lens of sufficient power in the focal plane of his portrait lens and achieved a great improvement in the field curvature and covering power.

M. Von Rohr, the well-known historian, reports that the photographs taken by Smyth with his Petzval–Smyth lens combination were of remarkable quality. For many years Smyth's simple but noble device seems to have been forgotten, or to say the least, neglected. In the year 1911, Von Rohr[7] (Carl Zeiss) introduced a lens combination comprising a portrait lens to which a negative field-flattener lens was attached near the focal plane (Fig. 6).

His design differs from the original Smyth arrangement in several ways. In order to obtain a useful back-focus clearance, he had to design the entire system as a unit, because when the field flattener is moved away from the exact focal plane, it immediately begins to affect all the aberrations of the main lens. To obtain another degree of freedom in his work of design, he introduced an airspace between the two elements of the front component of the portrait lens and was able to achieve a relative aperture as high as $f/1.8$. The lens consists of five single elements, separated by air. The spherical aberration (Fig. 6a) is well corrected, but the zone ($f/2.6$) shows a considerable amount of residual under-correction. Instead of flattening at least the meridional field, the designer seemed to be more interested in freedom from

astigmatism with the result that both fields were curved. Nevertheless, the improvement over the original Petzval portrait lens is immense.

The Smyth principle has been applied in the well-known Kodak Projection Ektanon lens,[8] shown in Fig. 7. It consists of the modified Petzval type and a field flattener, with a relative aperture as high as $f/1.6$. The aberrations (Fig. 7a) are such that this lens of 2-in. focal length resolves 90 lines/mm in the center of the projected image. Astigmatism and the curvatures of the meridional and sagittal field (Fig. 7b) show a considerable improvement over the lenses without the field flattener, and consequently there is a more satisfactory performance. A lens of 2-in. focal length will resolve 50 lines / mm in the corner of the 16-mm frame.

The New Projection Ektar Lens

The progressive improvement of lenses of the Petzval type, especially those embodying a field flattener, has been described in the previous paragraphs.

However, the demand for a 16-mm projection lens, comparable with the best used in 35-mm projection, is steadily increasing. Next to a high relative aperture it is imperative that the resolving power of such a lens should be of a higher order than ever before. These requirements have led to a new design, the Kodak Projection Ektar $f/1.5$ (Fig. 8).

This lens is fundamentally of the modified Petzval type to which a field flattener has been attached. To surpass the performance of previous projection lenses, the designer has not only added one element to the front component to reduce the zonal spherical aberration, but has also taken advantage of the new high-index glasses[9] of which elements 3 and 4 consist.

The zonal spherical aberration (Fig. 8a) has been reduced to a minimum. Astigmatism and field curvatures (Fig. 8b) also show a distinct improvement which has to be credited to the use of high-index low-dispersion glasses. These have already proved their value in other optical systems.[10] In the present case the use of these glasses relieves the field flattener of some of the burden of Petzval sum correction. In this way the flattening of the sagittal field (formerly the worse offender) has been solved satisfactorily. The relation of the two fields to one another is such that, by a slight bending of the field flattener, astigmatism could be brought to zero with both fields flat. However,

since the entire oblique pencil had to be considered and the oblique spherical aberration had shown a tendency to over-correction, a slight inward displacement of the sagittal and meridional focal points was necessary.

Fig. 9. A series of Projection Ektars.

The performance of this lens is indicated in the curves in Fig. 8a and 8b. It resolves better than 90 lines/mm over the entire 16-mm frame with a perfectly flat field. With respect to contrast, the lens has

proved to be a worthy descendant of its famous ancestor, the Petzval lens.

It was decided to manufacture a series of these $f/1.5$ Projection Ektar lenses in 2.062-in. barrels, the focal lengths being in geometrical progression as originally recommended by Rayton.[11] The choice of common ratio was based on the decision to allow two intermediate lenses to fall between the standard 2-in. and 3-in. sizes. The new focal lengths thus became 2¼ and 2⅝ in., at a common ratio of about 12% (Fig. 9). If this series were continued one step further in the long direction it would fall at 3½ in., but it was felt that this is probably too long for most civilian applications. However, longer sizes can, of course, be made if required.

In every case, the resolving power of 90 lines/mm has been rigidly maintained in manufacture, over the entire area of a flat 16-mm projector gate.

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The Metal-Diazonium System For Photographic Reproductions

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Summary—The metal-diazonium system for photographic reproduction, which has been developed in Philips Laboratory in Eindhoven in the course of the last few years, is based on the discovery that when a solution of a diazonium compound and a metal salt, say mercurous nitrate, is exposed to light, atomic metal — *in casu* mercury — is separated. The "latent" mercury image thus obtained can be transformed by physical development into a silver image and intensified. The light-sensitive system is obtained in the form of a film or sheet by impregnating a suitable carrier, say a strip of cellophane 40 μ thick, in a homogeneous solution of the said materials. The metal-diazonium system possesses an extremely high resolving power ($>$ 1000 lines/mm) and allows of working with a very high gamma (6–8) while on the other hand low gammas (1–2) can also easily be obtained by varying external factors, *viz.* the moisture content or the intensity of exposure. The light-sensitivity of the system is in cellophane several times (in paper some tens of times) greater than that of the usual diazotype printing papers. This system, which was originally intended only for producing distortion-free copies of Philips-Miller sound film, lends itself excellently, *inter alia,* for the copying of picture-sound films, thanks to the external variability of the gamma. The impregnating of the cellophane base takes place on printing machines designed for the purpose, while at the same time these machines are fitted with a device for regulating the moisture content of the base. The good photographic properties of the system and the very low cost of materials open great prospects for its application on a large scale in all sorts of fields. In addition to the sound film and the picture-sound film also the field of micro and macro documentation is regarded as an important domain for the application of the system.

The metal-diazonium system is a new light-sensitive system that has been worked out by a group of scientists in the Philips Laboratory at Eindhoven. It possesses a number of remarkable properties making it exceptionally suitable for the photographic reproduction of pictures as well as of sound. Something has already been said about this system in a previous article,[1] where it was shown by a comparison with the usual methods of reproduction what place the new system could occupy.

Here we shall give a more detailed description of the fundamental

[1] C. J. Dippel and K. J. Keuning, "Problems in photographic reproduction, in particular of sound-films," *Philips Tech. Rev.*, vol. 9, no. 3, pp. 65–72; 1947.

Reprinted from: *Philips Technical Review*, vol. 9, no. 10, pp. 289–300.

principles of the metal-diazonium system and after going more deeply into its properties show how it is realized and practiced, then concluding by dealing with a number of perspectives for the application of this new reproduction material.

Principle of the System

The Light-Sensitive Material

Diazonium salts have the general chemical formula

$$[R - N{\equiv}N]^{+}X^{-}$$

in which R is an aromatic radical and X some anion. These compounds have been used for quite a time already for photographic reproduction methods. They are most familiar and most widely used in diazotype, a light-printing process for the multiplication of technical drawings and suchlike (tracings) made on transparent material.

Just as with all reproduction methods based on diazonium compounds, the fundamentals of this light-printing process lie in the following properties:

(a) Coupled with certain phenols or amines, the diazonium salts form what are known as azodyestuffs.

(b) When a diazonium salt is exposed to light in the presence of water (water vapor) dissociation takes place and nitrogen is released. Schematically the reaction takes place as follows:

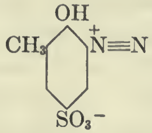
$$RN_2X + H_2O + h\,v \rightarrow \text{l.d.p.} + N_2 + HX. \qquad (1)$$

The light-decomposition product (l.d.p.) thus formed is no longer capable of forming a dyestuff. If, therefore, one exposes a "diazotype paper" on which a tracing is laid and then causes the reaction, (a) above, to take place, a dyestuff is formed only on those parts of the paper that have not been exposed to the light. In this way a positive copy is obtained direct from the tracing.

The difficulties and limitations referred to in the previous article[1] as being inherent in photographic reproduction with the usual silver-bromide and silver-chloride systems exist in a still higher degree with the diazonium processes hitherto known. They have not met with any appreciable success, for instance, in the reproduction of picture-sound films.

The new photo-chemical system described here is based on the discovery that the light-decomposition products obtained from certain diazonium compounds according to equation 1 are capable of releas-

ing the metal from suitable metal salts, for instance mercury from mercurous nitrate, gold from aurochloride, etc. As diazonium compound one may use for instance o-cresol-diazonium-sulphonic acid:



When an aqueous solution of this compound and, for example, mercurous nitrate, $Hg_2(NO_3)_2$, applied in a thin flat layer is exposed with light of a short wavelength (*e.g.* 3650 A) one may observe under the microscope small drops of metallic mercury at the places struck by the light. Thus a faint "mercury picture" is formed which might be compared to the "latent" picture in the usual method of photography with silver halogenides. And here, too, the "latent" picture can be intensified and made durable by developing. Contrary to the custom with silver halogenide photography, however, a so-called physical developing process is applied with our system. In view of the important part this developing method plays in the metal-diazonium system a separate section will be devoted to it below.

In order to show properly the difference from the old diazonium processes the point is stressed that only the second of the two characteristic properties of diazonium salts mentioned above, *viz.* the light decomposition, is utilized in the metal-diazonium system, the other property—formation of dyestuffs—playing no useful part in our system. The diazonium compound left on the unexposed parts is removed, while the exposed parts turn black (separation of metal). Thus we get instead of a positive copy a negative copy, as is the case with silver halogenides.

As to the practical realization of the system we shall revert to this later, but it is necessary to say something here about the manner in which the thin layer of the light-sensitive material is obtained. In this respect the new system differs fundamentally from the silver halogenide systems. With the latter systems an "emulsion" (more correctly: a suspension) of the light-sensitive substance, *e.g.* crystalline silver bromide, is made in gelatine and after a complicated and most precise ripening process this emulsion is cast on a celluloid film or a glass plate. In our case, on the other hand, a homogeneous solution is made of the diazonium compound and the metal salt and a suitable carrier is saturated with it. As carrier one may use for

instance paper or, as we have done in the most important applications, a transparent base of regenerated cellulose. This latter material (which is more commonly known under the name of cellophane and is widely used as packing material for shop goods) is used by us in the form of a reel of film 0.04 mm (0.0016 in.) thick. But in principle one may also use with our system a gelatinous layer on celluloid or glass. One may also use the cellulose acetate film (so-called safety film) commonly applied for substandard films and by saponification make the surface suitable to absorb the aqueous solution of our light-sensitive system.

Physical Developing Process

What takes place in the so-called physical developing process in photography may be resolved into a phenomenon often met with in nature and in technology and which might be described as follows. When particles from an over-saturated solution or vapor begin to precipitate they show a preference for places where certain "nuclei" are present. If these nuclei are distributed locally in such a way as to form a "picture," maybe so faint that the eye cannot see it, then the picture is intensified by this selective precipitation of particles and may thereby be made visible.

A familiar phenomenon known to everyone is the picture formed by condensation on a smudged glass window when the window is breathed upon or cold air blows upon it from one side, water vapor condensing on the traces of dirt acting as nuclei and making visible figures.[2] Another example that may be given is that of the Wilson camera, where droplets of water from an oversaturated vapor condense on electrically charged particles and thus make visible the path followed by an ionizing particle.

Turning particularly to photography, we see that both chemical and physical developing methods are in use, the latter more particularly in cases where negatives have to be intensified. Let us first consider what ordinary chemical developing comprises. A silver bromide film or plate is placed in a developing bath containing a reducing agent, for instance metol or hydrochinon, in a generally alkaline solution. The grains of silver bromide, in which silver nuclei have

[2] In the familiar game of writing or drawing on a glass window with a wet finger, when some days later the writing is made visible by breathing upon it, we have examples of negative pictures; the window is more or less uniformly covered with "dirt," which is removed by the finger (or at least partly so) or else a thin film of grease is left behind, so that less vapor is condensed on the writing than on the rest of the window.

been formed by the exposure (groups of say 100 atoms of metallic silver), are reduced by the developer entirely to silver, while the unexposed or too weakly exposed grains remain untouched. After this developing, as is known, the remaining silver bromide is removed with the aid of sodium thiosulfate (fixing).

If the picture thus obtained is not dense enough, it can be intensified by physical development. The film is placed in a weak acid solution containing silver nitrate in addition to a reducing agent, for which metol or hydrochinon can again be used. In the solution the silver nitrate is gradually reduced to silver, the solution becoming oversaturated, as it were, with atomic silver, which precipitates preferably on those places where "silver nuclei" are already present, *i.e.* on the exposed parts of the film.[3]

It is perhaps of interest to note that this physical developing process can be applied also to the "latent," not yet chemically developed, image on the exposed silver bromide film. One can start by fixing the exposed film, thus removing all the silver bromide and leaving only the silver nuclei formed by the exposure, the latter then acting as nuclei for the subsequent physical development as described above.

The oldest photographic process, daguerreotype, was likewise based upon a physical method of developing; an image was formed on an iodized silver plate and the exposed plate was treated with oversaturated mercury vapor. Mercury was thereby condensed on the exposed parts of the plate and the picture became visible.

After these examples the method of physical developing applied with the metal-diazonium system does not need much more explanation. The carrier, containing for instance o-cresol-diazonium-sulfonic acid and mercurous nitrate, is placed after exposure in a suitable solution of silver nitrate and a reducing agent. Reaction then takes place between the locally formed metallic mercury and the silver nitrate, the mercury dissolving and silver precipitating at those places, the latent mercury picture thus being transformed into a latent silver picture. Moreover, by reduction metallic silver is gradually formed in the solution. The local metal deposits already present act as nuclei upon which more and more silver is deposited as new silver is formed in the solution, thereby developing the picture.

[3] In this case the physical developing process comprises also a chemical process. From this it appears that the name "physical development," which we use because it has already been introduced, does not express the essential difference from the actual chemical process of developing. The difference as we see it lies in the fact that in chemical development the metal from which the picture is built up is already present in the appointed place prior to developing in any form whatever, whereas in the physical development it is only brought into its appointed place by the developing process.

One of the essential factors in this process is the rapidity with which the silver is formed in the solution by reduction. If this takes place very rapidly one gets instead of a selective deposit a more or less evenly spread deposit of silver, a phenomenon that can even be turned to advantage for making homogeneous silver mirrors. By giving the solution, for instance, a suitable degree of acidity one can regulate the speed of the spontaneous reduction of the silver nitrate and cause practically all the silver formed during the developing process to precipitate on the nuclei of the picture, to the exclusion of almost all undesired precipitation of silver on the unexposed parts. The negative may not be kept in the developing bath longer than the time taken for developing, because the developer is an unstable system and liable in time to cause a spontaneous flocculation of all the silver, which then precipitates anywhere.

We will not conclude this explanation of the principles of the metal-diazonium system without remarking that here only a very rough and greatly simplified representation of the processes has been given. To understand the connection between the photographic properties obtained and the numerous variable factors of the system it has been necessary to study deeply the mechanism of the light decomposing reaction (equation 1) and of the developing process. It may be possible at a later date to go more deeply into the problems arising, some of which are still unsolved.

PROPERTIES OF THE METAL-DIAZONIUM SYSTEM

Resolving Power

In the article previously quoted[1] it was explained that for photographic reproduction, especially of picture-sound films, a high resolving power is favorable. However, there is a limitation in this respect, in that it tends to spoil the quality of reproduction (unsharp pictures, distortion of high frequencies); or, when trying to avoid this drawback, it necessitates a greater length of film (the picture may not be too small), the same applying for the speed of the film on account of the sound.

The positive films commonly used for copying picture-sound films have a resolving power of between 50 and 75 lines/mm, so that when projecting gratings finer than what corresponds to this number of lines per mm the lines run into each other and therefore can no longer be made visible separately. Some new Kodak films for special

purposes have a resolving power as high as 160 lines/mm. *The metal-diazonium system is quite capable of resolving 1000 lines/mm.* It is even possible that its resolving power is still greater, for the optical means used in determining this power have themselves a limited resolving power, which in our case did not reach further than the said limit of 1000 lines/mm.

In other laboratories too, *i.a.* Kodak, it has for some time been possible to make reproductions with an extremely high resolving power, of the order of 1000 lines/mm.[4] Collodion plates or so-called Lippmann emulsions are used. Except for the already known application of wet collodion plates for making autotypes, as far as we know none of these processes has been suitably developed for general use.

The high resolving power of the metal-diazonium system is due for a large part to the fact already mentioned that the light-sensitive material is not used in the form of an emulsion but in that of a homogeneous solution; the unexposed system is quite free of grains, so that there is very little diffusion of light in the sensitized material. If a large quantity of light reaches one point then in the circle round about that point where undesired light reaches, owing to diffusion, the quantity of that light is extremely small. Moreover, and this is the second cause of the high resolving power, that circle (the diffusion halo) remains extremely small owing to the fact that with the chosen concentration of the chemical components in the light-sensitive solution the active light is very strongly absorbed. Consequently the diffused light does not reach far.

Owing to the strong absorption the direct light thrown upon the carrier upon exposure stays in the top layer. Consequently the metal forming the picture is limited to a thin layer. This is likewise of importance for the high resolving power, for it is not sufficient that details are recorded well separated in the carrier—they must also be reproduced separately either for copying or for projection. Owing to the fact that one never uses perfectly parallel light beams, the thicker the picture layer the more details are lost.[5]

[4] See, for instance, *J. Sci. Instr.*, vol. 18, pp. 66–67; 1941, where an account is given of the "Kodak maximum resolution plate," which can resolve 600 or even 1200 lines/mm. Similar results have been reported by H. Frieser, *Z. wiss. Phot.*, vol. 40, p. 132; 1941. For older methods, see E. v. Angerer, *Wissenschaftliche Photographie*, p. 136 *et seq.* Akad. Verl. Leipzig, 1931.

[5] Also in the old diazotype processes based on diazonium compounds the material is free of grains, but the resolving power is not very high, because, *i.a.*, the picture is rather thick: owing to the relatively small absorption a thick layer of dyestuff is necessary for adequate "density." Furthermore the formation of the dyestuff is a relatively slow reaction, so that after the exposure a noticeable diffusion takes place before the (fixed) molecules of the dyestuff are formed.

Figure 1, the magnified reproduction of a micro-document made with the new system, demonstrates the high resolving power.

The Gamma Value

Every photographic picture, be it positive or negative, has a certain characteristic density curve which indicates the density obtained for any exposure $E = I \cdot t$ (I luminous intensity, t exposure time). The density D[6] is usually plotted as a function of log E; see for instance Fig. 2. For many light-sensitive materials the density curve shows a

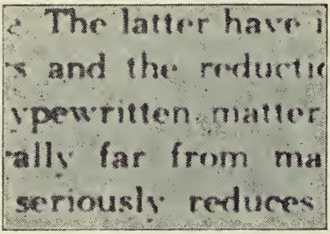

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Fig. 1. A reproduction, linearly enlarged about 250 ×, of a piece of a micro-document recorded with the metal-diazonium system in cellophane. The size of this piece in the micro-document was 0.012 × 0.017 cm and the height of the letters 12 microns. The good definition of the reproduced letters gives an idea of the exceptionally high resolving power of the system (> 1000 lines/mm).

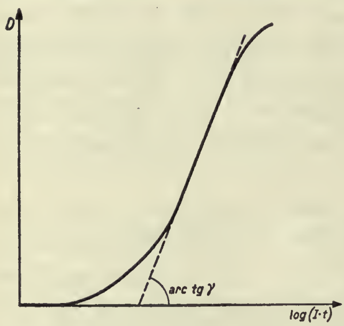


Fig. 2. Example of a density curve $D = f(\log I \cdot t)$ of a photographic picture. The maximum slope of the curve lying in the practically rectilinear part in the middle is the gamma.

more or less extended, practically rectilinear part, where at the same time the slope of the curve is greatest. The whole curve is in fact characterised by this slope, the gamma, because this is decisive for the gradation in the reproduced picture (reproduction of the shades of brightness). It is well known that with the usual silver halogenide systems the value of the gamma depends largely upon the emulsion and is further particularly determined by the conditions of developing (temperature and composition of the developing bath, time taken in developing). Common values in practice vary from 0.5–2.5.

When applied in a suitable manner, as will be defined below, the

[6] Defined as $D = \log i_0/i$, where i is the portion of an incident quantity of light i_0 that the blackened plate or film allows to pass through.

metal-diazonium system has very *much higher gammas, e.g. 6–8.* In the previous article[1] it has been explained what important advantages this offers for instance for sound reproduction. Since with a high gamma a relatively small reduction in the exposure intensity is sufficient to bring about a transition from the "greatest density" to the "smallest density," only the innermost part of the circle diffusion halo already referred to is noticeably blackened. Thus the high gamma promotes a high resolving power and therefore in the case of sound reproduction promotes good reproduction of the high frequencies. The high gamma yields particular advantages in the copying of Philips-Miller film, as we have seen in the previous article; the "lens effect" arising in this process is rendered harmless without any other measures being necessary.[7]

External Variability of the Gamma

In sound reproduction by the amplitude system, advantage can safely be taken of a high gamma, because in principle we have only to do with two densities, a very low one in the transparent sound track and a very high one for the rest of the film. There are all sorts of other applications where the same holds, *e.g.* in micro and macro documentation, to be discussed below. In picture reproduction, on the other hand, a whole series of shades of brightness (half tones) has to be reproduced by corresponding, continuously varying densities. To attain this it is necessary to satisfy the Goldberg condition,[8] as a result of which in picture reproduction one has to work with relatively low gammas, *e.g.* 1.5–2.5.

Now such gammas and still lower values can be obtained quite easily with the metal-diazonium system. This is possible not only by a suitable choice of the composition of the system but also by making use of the following important feature: *the gamma of a metal-diazonium-cellophane system can be greatly influenced by the moisture content of the film during exposure and likewise by the duration of the exposure.* The very high gammas referred to under the previous heading occur

[7] Also the so-called wedge effect with the Philips-Miller film is rendered harmless by the high gamma. When the transparent sound track in a "Philimil" film is cut with the wedge-shaped chisel, which is a characteristic feature of the Philips-Miller system, an oblique edge is left on the top layer, and when copying this results in a gradual transition from the maximum to the minimum density. In itself this does no harm, but aberrations arise if there is any variation in the thickness or the density of the covering layer. The higher the gamma, the narrower this edge transition shows on the copy and the smaller the aberration.

[8] See the explanation in the article quoted in footnote 1.

when the cellophane film is dry, that is to say when its moisture content is not more than say 15% by weight, and when the film is exposed with a great intensity (and corresponding short exposure time). If the moisture content is increased to 25–30% by weight, then one gets the low gammas required for good picture reproduction.

Figure 3 indicates the relation between the gamma value and the moisture content of a cellophane film for certain concentrations of the ingredients and under certain conditions of exposure, developing, etc. There the following refinement has been applied. Instead of showing the gamma indicating the maximum slope of the density curve, the values g_1, g_2, g_3 have been plotted of the average slope that the density curve assumes in three consecutive density intervals of

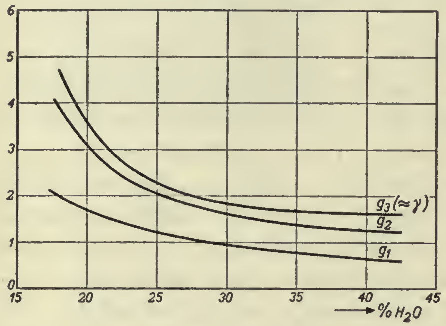


Fig. 3. Effect of the moisture content of the cellophane film upon the gamma of the mercury-diazonium system in the film for a certain concentration of the ingredients and a certain manner of exposure and developing. The lines plotted represent the average slopes g_1, g_2, g_3 of the density curve in three different density areas; g_3 is practically equal to the maximum slope γ.

the most importance in practice, *viz.* between $D = 0.05$ and 0.5 (high lights); $D = 0.5$ and 1.0 (intermediate tones); $D = 1.0$ and 1.5 (shadows). The value g_3 is generally practically equal to the maximum slope defined as γ.

This defined description of the gradation, often applied with silver halogenide systems and sometimes even extended to five intervals, is desired when one has a group of density curves which do not all have a rectilinear part with maximum slope in the density area required. This is also frequently the case with the metal-diazonium-cellophane system, with which it is possible to get a large variety of density curves under the influence of the numerous variables.

The fact that the gamma, or in other words the density curve, depends upon the duration of exposure t means that the density D is no longer a function of the product $I \cdot t$ but of I and t separately. Therefore instead of a two-dimensional density curve, to describe fully the photographic behavior of the system we need a solid figure in which the curved plane $D = f(I, t)$ is represented. Such a plane is drawn in perspective in Fig. 4. It must be borne in mind that by

varying the moisture content, the conditions of developing, etc., a different plane is obtained every time. The "density curve" of a picture taken with an exposure time t_1 is the cross section of the density plane parallel to the D and I axes which is intersected by the t axis at t_1. From Fig. 4 it is clearly seen that for different values of t one obtains density curves with a different slope (gamma). A number of these curves are drawn in Fig. 5, while in Fig. 6 the slopes g_1, g_2, g_3 ($\approx \gamma$) of these curves are plotted as a function of t.

From this it also follows that the relation between $\log I$ and $\log t$ for a constant density D (horizontal cross sections of the curved plane at different heights; see Fig. 4) is given by lines the slope of which must gradually change with varying D. Whereas in the simplest case, which was assumed in Fig. 2, D was only a function of $I \cdot t$ so that for the given D we had $\log I + p \log t = \text{constant}$ with $p = 1$, in our case as a rule $p \neq 1$. This is the familiar Schwarzschild effect. Moreover, according to the foregoing, in our case the Schwarzschild exponent p (slope of the $\log I$-$\log t$ lines in the area where these may be regarded as straight) depends also upon the density.

Figures 3 and 6 give a clear picture of the great variability of the gamma in the metal-diazonium system. Now it is important to note that this is an *external variability:* on one and the same material and with one developing process we can make copies with a high gamma and with a low gamma. This creates not only the possibility already mentioned of copying both sound and pictures each with the most favorable gamma, but also an entirely new possibility of copying sound and picture side by side on one film and developing them together without necessitating a compromise in the gamma such as is characteristic for the present picture-sound film technique (see the previous article[1]). All that is necessary is either to select the exposure intensities separately for the copying of the pictures and for the copying of the sound track, or else to vary the moisture content of the cellophane band between the two places where in the printing machine first the picture is copied and farther on the sound track is copied (it may be that both measures have to be applied together).

In a similar manner we can also print on one film the pictures of different scenes with a different gamma while requiring only one developing process! This offers the possibility of correcting any exposure or developing variations in the negatives.

Light Sensitivity

The light sensitivity of the metal-diazonium system depends not only upon the choice of the ingredients, etc., but also varies with dif-

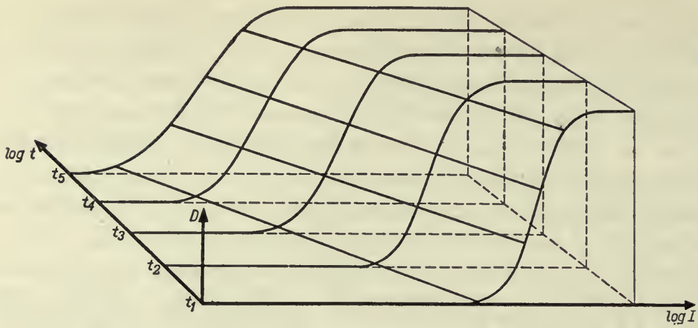


Fig. 4. The gamma of the metal-diazonium system also depends, *i.a.*, upon the intensity of exposure I. Therefore the density D is not fully determined by the product $I \cdot t$; the photographic behavior of the system has to be described by a solid density plane $D = f(I, t)$. This plane is drawn here for given concentrations, moisture content, developing, etc., in perspective. Log I and log t are plotted as independent variables.

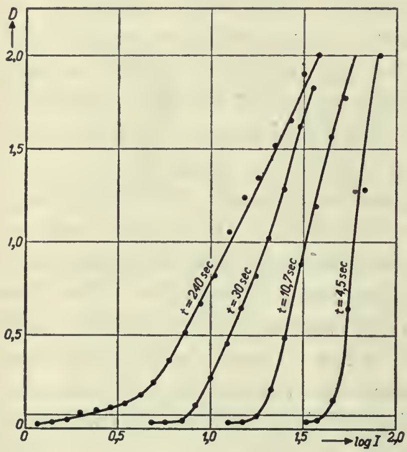


Fig. 5. From the density plane drawn in Fig. 4 it is possible to find for any exposure time t the density curve $D = f(I)$ of the picture obtained with that exposure time, by taking a cross section of the plane perpendicular to the t-axis at the level of that time. Such cross sections are represented here for various exposure times. It is seen that curves are obtained with different slopes (different gammas).

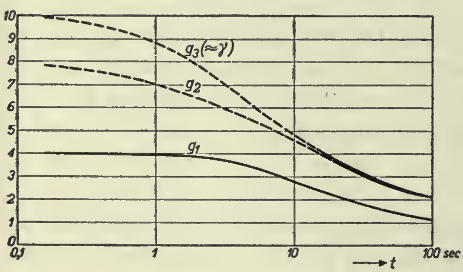


Fig. 6. The slopes g_1, g_2, g_3 of the curves of Fig. 5 plotted as functions of the exposure time t.

ferent carriers. When cellophane is used the sensitivity may be several times greater than that of the known diazotype papers. Yet with paper as a carrier the sensitivity of the system is greater by a factor of 10. For instance with mercury as metal the metal-diazonium paper can easily be made 20–25 times as sensitive as the positive diazotype papers, a gain which just makes it possible to produce enlargements by the light-printing process (see the last section). Still this is a factor 10^4 below the sensitivity of silver bromide enlargement papers.

There is, therefore, no question that the metal-diazonium system as at present developed could compete with the materials commonly used for photographic recording. As a matter of fact the spectral zone in which the metal-diazonium system is sensitive is too limited for this purpose. The sensitivity of the mercury-diazonium system lies mainly in the near ultraviolet with a maximum in the vicinity of 3900 A and not extending beyond the bluish green (about 5000 A).

For application as reproduction material, however, in most cases neither the low sensitivity nor the limitation of the spectral area constitutes any objection. One only needs to use for the copying process a light source possessing great luminous intensity in the said range of the ultraviolet. Super-high-pressure mercury lamps with water cooling are excellently suited for this purpose. With these lamps the intensity of light that can be reached when exposing the film is so great that a film can be copied at fairly great speeds, for instance 20 meters per minute.

An important advantage of the limited spectral sensitivity lies in the fact that the whole working of the system can take place under a bright sodium light, since in the wavelength range of the sodium lines (5890 A) the sensitivity is practically nil.

A great deal of work has been done in this laboratory in respect to the question as to what determines the sensitivity of the metal-diazonium system. In the particular case where mercury is employed as a metal it was demonstrated that the process of the formation of the latent mercury picture has a quanta yield of about 50%; for an average of two exposure quanta one atom of metallic mercury is formed. This means that the "primary" sensitivity is of the same order as that of the silver halogenide systems. According to the conclusions provisionally reached from an investigation into the highly complicated mechanism, the cause of the so much smaller resulting sensitiveness of our system is to be sought rather in the further history of the nuclei to be developed; the metallic atoms combine to form larger particles. As already stated, under a very strong magnification (about 800 ×) these particles may be seen in the latent picture. Thus in this stage the metal is rather coarsely dispersed and in the physical developing process the resultant density is all the less according as the (given) quantity of metal of the latent picture is more coarsely distributed.

The influence of the moisture content and the intensity of the exposure upon the gamma is also closely related to the history of the primary metallic atoms and of the metallic nuclei prior to developing.

Durability

When talking of durability in the case of the metal-diazonium system we have to differentiate between the exposed and the unexposed state. The unexposed system appears to have as yet too little durability for a sensitized cellophane film, for instance, to be kept in stock until one has need of it. For the most important applications that we have in mind, however, this forms no serious objection, as will be made clear below.

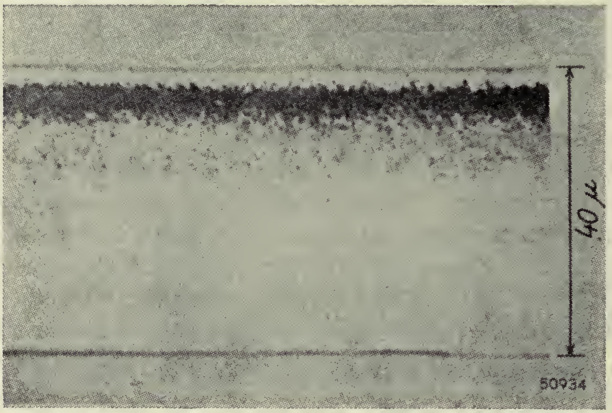


Fig. 7. Microtome cross section of a sensitized cellophane film 40 microns thick after exposure and developing. The particles of silver from which the picture is built up lie in a thin layer a few microns below the surface.

After exposure and developing one has a picture that will keep practically indefinitely: as already mentioned above, the definitive picture consists of metallic silver, just as is the case with silver halogenide systems, and thus is perfectly proof against atmospheric influences and light (such contrary to the dyestuff pictures of the old diazotype papers). Furthermore, the picture on a cellophane film is protected in a peculiar manner against mechanical damage: when a microtome section of such a film is cut and examined under the microscope it will be seen that the extremely thin layer containing the metallic silver of the image (see above) does not lie on the surface of the film but a few microns below it; see Fig. 7. We cannot go into the ex-

planation of this here, but it has the welcome practical advantage that the actual picture is protected against scratching, etc., by the thin layer of clear cellophane covering it.

Economy

It is to be expected that the cost of the metal-diazonium system will be relatively low, a factor that will prove to be of great weight for various applications. How is it that the system turns out to be so economical? In the first place there is the choice of the carrier, cellophane being the cheapest material imaginable for this purpose. Another important factor is the limited consumption of silver, it being a characteristic of the physical developing method that the sensitive material itself need not contain any silver; the silver comes from the developer and is added to the negative, and the developing can be so controlled that not much more silver need be used than is necessary for building up the ultimate silver picture. With the usual silver halogenide systems, on the other hand, a very high percentage of silver is wasted; it comes out of the exposed film in the fixing bath and cannot be recovered except at considerable expense.

Of further importance is the very simple method of manufacture, as will be explained under the next heading.

Yet another advantage to be mentioned in connection with the economy of the metal-diazonium cellophane system is the saving in volume and the attendant ease of storage and transport. A cellophane film 40 microns thick and say 300 m long winds up into a reel about 13 cm in diameter, whereas a normal celluloid film of 300 m length forms a reel 26 cm in diameter.

REALIZATION OF THE METAL-DIAZONIUM SYSTEM

The metal-diazonium system can be realized in quite different ways according to the use intended and the carrier employed. As a typical example we will consider here the application of the system for the copying of picture-sound films with cellophane as the carrier.

Just as is the case with the common silver bromide films, so with the cellophane film the actual copying process takes place on a machine where both the negative and the positive films are caused to pass along under a lamp simultaneously. Now we have already said that the cellophane film is sensitized by impregnating it in its entirety with the solution containing the light-sensitive system. Further it has been stated that the cellophane film sensitized in this manner has only

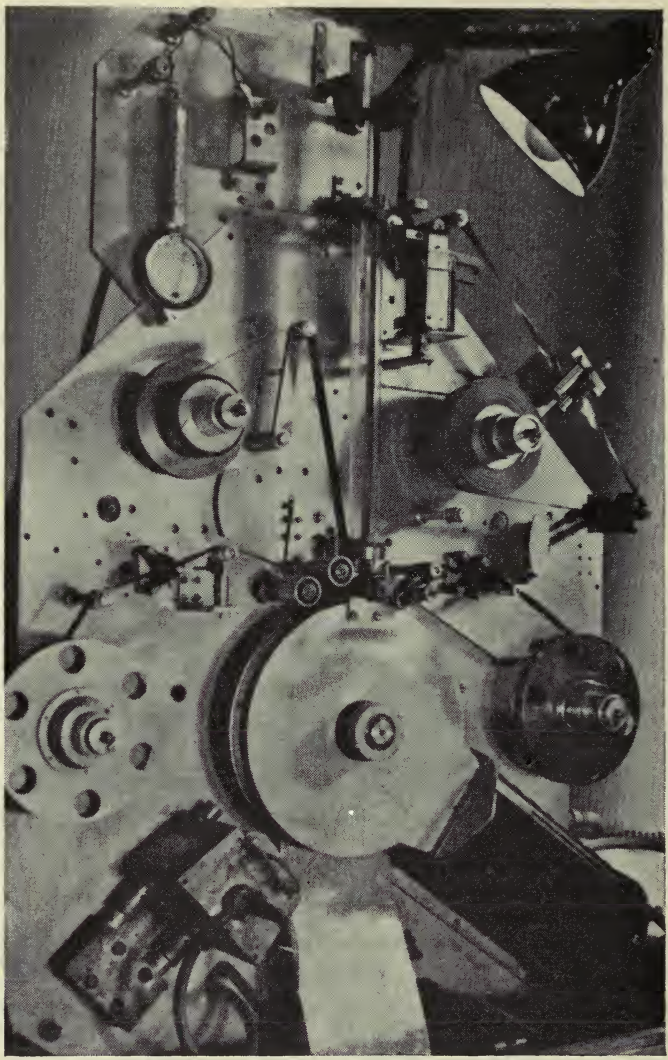


Fig. 8. Printing machine on which a cellophane film is first impregnated in the light-sensitive solution, then dried to the desired moisture content and after that exposed. The film is fed in from the right, impregnated in the bath at the top on the right, dried in the vertical tube and printed on the drum in the middle at the bottom of the photo, where it is brought into contact with the original film to be copied, the two films passing underneath the lamp simultaneously. (For drying the film when running at a high speed several tubes were used; with the latest machine drying is done by high-frequency heating.)

a limited durability. The difficulties that this might involve have now been overcome in a very simple way by *combining the sensitizing process with the printing process*, the impregnating of the cellophane film and the exposure taking place on the same machine in succession.

The fact that we have here an extremely simple and economical *modus operandi* is quite evident when comparing it with the manufacture of silver bromide film, where the preparation of the carrier, the preparation and ripening of the emulsion, the casting of the emulsion on the celluloid film and later the copying are all done in separate departments.

The first mentioned method has also been found to improve considerably the reproducibility of the properties of the film.

Between the impregnating and the exposing of the cellophane film this has to be dried to a moisture content corresponding to the desired gamma. Further, it must be possible to reduce still further the moisture content between the exposure of the picture and that of the sound track on the film if such should be desired. This can be done by passing the film through a tube with conditioned air, as seen in Fig. 8, or by means of high-frequency heating.

Possibilities of Application

The system is still too young to allow of any data being given as to its applications, but the experience so far gained with it opens such interesting perspectives that a brief outline of some of its possible uses may well be given here.

Sound Film

A stereophonic sound track has been made on 7-mm cellophane films by copying a stereophonic Philips-Miller film.[9] Thanks to the sharp definition of the mechanically recorded original and the high resolving power of the copying material an exceptionally good quality of sound is obtained, in respect to the reproduction of the high frequencies and the absence of nonlinear distortion (see the article quoted in footnote[1]). This good quality of reproduction together with the enhanced "naturalness" obtained by stereophony seem to us to constitute the requisites for imparting to "mechanical" music the original musical character.

[9] K. de Boer, "Stereophonic recording on Philips-Miller film," *Philips Tech. Rev.*, vol. 6, pp. 80–84; 1941.

Partly by reason of the low cost of the reproduction method, it is in principle possible that this ideal method of reproducing music will come within the reach of everyone for use in the home. An attraction of the cellophane films used for this method is that a music film with a playing time of one hour forms a reel no more than 18 cm in diameter (playing speed 32 cm per sec); see Fig. 9. This is

Fig. 9. An illustration of the compactness of a recording of music on cellophane film. Music that takes one hour to play can be recorded stereophonically on a film reel of the size of that shown in the illustration. For the same playing time (without stereophony!) 10 gramophone records of 25 cm diameter are required.

due on the one hand to the extreme thinness of the cellophane film (40 microns) and on the other hand to the fact that it is possible to print on a 7-mm film two stereophonic sound tracks (thus in all four tracks).

A piece of music of one hour can be reproduced without any of the interruptions that are unavoidable with the gramophone even when using an automatic record-changer.

Picture-Sound Film

Apart from the cinema there is a wide field of possibilities awaiting the "talkies." Such could be used on a large scale for entertainment in the home, for educational purposes in schools, for advertising, etc., provided they are cheap and of good quality. The 8-mm film, which would seem to lend itself best to this purpose, has not yet been widely used because it is still too expensive and owing to the limited resolving power of the common emulsions the pictures are not sharp enough; furthermore it does not leave any room for the sound track. Though the sound track is applied on a 16-mm film the quality of the sound reproduction is not all one would desire.

Now the metal-diazonium system as a copying material presents a situation that is more favorable in many respects: apart from the possibility of making a sound track even on an 8-mm film, on a 16-mm film a better sound quality can be obtained than has hitherto been possible, partly due to the high resolving power and partly by reason of the variability of the gamma. Both of these factors also help in improving the picture quality—as is clearly noticeable on a contact print of a very fine-grained film, *e.g.* Isopan FF—although a limit is set to the sharpness of the picture by the limited resolving power of the original film (about 55–75 lines/mm) and possibly of the optical system of the camera. Finally the film could be cheaper.

The same considerations apply for the copying of standard 35-mm films on the new system.

For playing the very thin cellophane films special projectors are required. Figure 10 shows a model of a home cinema equipped with such a projector. If normal projectors are still to be used then the metal-diazonium system will have to be applied in or on a thicker carrier (say 130 microns thick), but then of course one loses the advantage of the great compactness of film reels with a long playing time.

Micro-Documentation

Micro-documentation is a comparatively young branch of the technique of reproduction, but it seems that a surprising development may be expected in this very direction.

The name itself already expresses its meaning: the recording of documents on a very small scale. The need for this may be due to various reasons. In some cases it is resorted to because the documents are so bulky or would become so bulky as to constitute a problem for

their filing, storage, handling or transportation; examples are the catalogs of large libraries, card index systems of large telephone exchanges or of the registers of births, deaths and marriages in large cities, etc. There are other cases where micro-documentation is applied because reproduction on the normal scale is too expensive, as for instance

Fig. 10. Model of a home cinema fitted with a special projector (mounted in the cabinet) for cellophane film. The projected picture satisfies high requirements regarding sharpness as well as gradation.

the copying of publications by libraries, or for the air-mailing of documents where weight is a big consideration, etc.

Obviously the higher the resolving power of the material used for the photographic reproduction, the smaller the size of the reduced document. With the extremely high resolving power of our metal-diazo-

Fig. 11. Three small sheets of metal-diazonium paper on which the complete contents of a book of 330 pp. have been reduced. Each page of the book is reduced on the paper to a size of 5 × 7 mm. The reproduced book is quite legible with a simple reading apparatus.

nium system it is possible to make a perfect record of a whole page of printing of the size of an 8 × 11½ in. periodical on an area of 0.6 by 0.9 mm, the height of the letters being about 12 microns.

It cannot be predicted whether one will ever go as far as such an extremely small size with the present stage of development of microdocumentation. For the present the sizes of, for instance, 5 × 7 or 2 × 3 mm seem desirable.

If one keeps to the larger dimensions of say 5×7 mm per page then the high resolving power of the metal-diazonium system is not utilized to its fullest extent, but even so this material will prove to be of great advantage owing to its low cost. Large tabular works, encyclopedias, etc., which can now practically only be consulted in libraries, could be reproduced on such a small scale on this inexpensive material as to be brought within the reach of anyone having occasion to read such works from time to time. Micro-reproductions can be read with a simple reading apparatus. The saving in volume is astonishing, even with the relatively large size of 5×7 mm, for a series of large books totaling 10,000 pages can be reduced to a pocket-size booklet of 100 pp. Three such pages, compared with the original normal book, are shown in Fig. 11.

Macro-Documentation

As the last field of application for the metal-diazonium system we would mention that of macro-documentation, which has already become of common usage in the form of diazotype and blueprinting and photocopying directly on a legible scale. Owing to the nature of the documents to which this process is applied (drawings, specifications, etc.), for this purpose the metal-diazonium system would be employed in paper. The paper is sensitized on both sides, so that it can be used on both sides for different copies; it does not curl up, and on account of its two-sided use it sometimes means a considerable saving in volume. Furthermore the image (a silver picture) gives a very rich contrast, with a pleasant tone (neutral grey), and is quite stable, properties which are often so lacking in diazotype and blueprinting processes. Of particular importance, however, is the possibility of making enlargements with metal-diazonium paper with exposure times that are practicable (for instance 1–5 seconds, depending upon the size). Thus we get a very efficient working method: wherever such is desired on account of frequent use, documents recorded on a micro-film can be enlarged again on metal-diazonium paper.

Proposed Bylaw Amendment

The proposed Amendment to the Society's Bylaws that appears on the following pages was approved by the Board of Governors at its January 31st meeting, and is now ready for consideration by the voting members of the Society. At a Business Meeting now scheduled for the Opening Session of the 67th Convention in Chicago on April 24th, members will be asked to submit their comments or criticisms of the proposal and then vote on the adoption of the Amendment. If approved, the Amendment will take effect at once and will be published with the Constitution in the May issue of the Journal.

This is the second basic alteration of the rules governing the Society to be considered as a result of a three-year study of the Constitution, Bylaws and Administrative Practices. The first, developed early in 1949, produced the Constitutional Amendment, including the change of the Society's name, discussed at the Annual Business Meeting on October 10th in Hollywood, and subsequently approved by the voting membership for adoption as of January 1, 1950.

A special Committee on Revision of the Constitution and Bylaws was authorized by the Board of Governors and first appointed on January 23, 1947, by then President, Loren L. Ryder. It has been continued by President Earl I. Sponable and will now turn its attention to the task of preparing a parallel revision of the Administrative Practices.

The guiding principle in this work has been that of eliminating excess verbiage, together with a careful defining of committee procedures and responsibilities, where necessary. Examples of the effect of this reappraisal are the recent changes in organization of certain engineering committees, adopted on recommendation of J. A. Maurer, former Engineering Vice-President, and F. E. Carlson, Chairman of the Standards Committee. Greater responsibility for preparatory work on standards has been placed on members of the Standards Committee, which is now made up largely of chairmen of the several engineering committees.

Members are urged to compare the following proposed Amendment with the present Bylaws, last published in the Journal in April, 1949, p. 463. The recent Constitutional Amendment, including the change of name, last appeared, in the form as finally adopted, in the September, 1949, Journal, p. 306. All voting members who can arrange to attend the April 24th Business Meeting are encouraged to do so and are invited to discuss freely the merits of the following proposal:

BYLAWS OF THE SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

BYLAW I

MEMBERSHIP

Sec. 1. Membership of the Society shall consist of the following grades: Honorary members, Sustaining members, Fellows, Active members, Associate members and Student members.

An *Honorary member* is one who has performed eminent service in the advancement of engineering in motion pictures, television, or allied arts. An Honorary member shall be entitled to vote and to hold any office in the Society.

A *Sustaining member* is an individual, company, or corporation subscribing substantially to the financial support of the Society.

A *Fellow* is one who shall be not less than thirty years of age and who shall by his proficiency and contributions have attained to an outstanding rank among engineers or executives of the motion picture or television industries. A Fellow shall be entitled to vote and to hold any office in the Society.

An *Active member* is one who shall be not less than twenty-five years of age and shall be or shall have been either one or an equivalent combination of the following:

(a) An engineer or scientist in motion picture, television or allied arts. As such he shall have performed and taken responsibility for important engineering or scientific work in these arts and shall have been in the active practice of his profession for at least three years, or

(b) A teacher of motion picture, television or allied subjects for at least six years in a school of recognized standing in which he shall have been conducting a major course in at least one of such fields, or

(c) A person who by invention or by contribution to the advancement of engineering or science in motion picture, television or allied arts, or to the technical literature thereof, has attained a standing equivalent to that required for Active membership in (a), or

(d) An executive who for at least three years has had under his direction important engineering or responsible work in the motion picture, television or allied industries and who is qualified for direct supervision of the technical or scientific features of such activities. An Active member shall be entitled to vote and to hold any office in the Society.

An *Associate member* is one who shall be not less than eighteen years of age, and shall be a person who is interested in the study of motion picture or television technical problems or connected with the application of them. An Associate member is not privileged to vote, to hold office or to act as chairman of any committee, although he may serve upon any committee to which he may be appointed; and, when so appointed, shall be entitled to the full voting privileges on action taken by the committee.

A *Student member* is any person registered as a student, graduate or undergraduate, in a college, university, or other educational institution of like scholastic standing, who evidences interest in motion picture or television technology. Membership in this grade shall not extend more than one year beyond the termination of the student status described above. A student member shall have the same privileges as an Associate member of the Society.

Sec. 2. All applications for membership or transfer should be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow grades may not be applied for.

Sec. 3. (a) Honorary membership may be granted upon recommendation of the Honorary Membership Committee when confirmed first by a three-fourths majority vote of those present at a meeting of the Board of Governors, and then by a four-fifths majority vote of all voting members present at any regular meeting or at a special meeting called as stated in the bylaws. An Honorary member shall be exempt from the payment of all dues.

(b) Upon recommendation of the Fellow Award Committee, when confirmed by a three-fourths majority vote by those present at a meeting of the Board of Governors, an Active member may be made a Fellow.

(c) An Applicant for Active membership shall give as references at least two mem-

bers of the grade applied for or of a higher grade. Applicants shall be elected to membership by a three-fourths majority vote of the entire membership of the appropriate Admissions Committee. An applicant may appeal to the Board of Governors if not satisfied with the action of the Admissions Committee, in which case approval of at least three-fourths of those present at a meeting of the Board of Governors shall be required for election to membership or to change the action taken by the Admissions Committee.

(d) An applicant for Associate membership shall give as reference one member of the Society, or two persons not members of the Society who are associated with the motion picture, television, or allied industry. Applicants shall be elected to membership by approval of the Chairman of the appropriate Admissions Committee.

(e) An applicant for Student membership shall be sponsored by a member of the Society, or by a member of the staff of the department of the institution he is attending, this faculty member not necessarily being a member of the Society. Applicants shall be elected to membership by approval of the Chairman of the appropriate admissions committee.

Sec. 4. Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors, provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

BYLAW II

OFFICERS

Sec. 1. An officer or governor shall be an Honorary member, Fellow, or an Active member.

BYLAW III

BOARD OF GOVERNORS

Sec. 1. The Board of Governors shall transact the business of the Society in accordance with the Constitution and Bylaws.

Sec. 2. The Board of Governors may act on special resolutions between meetings, by letter ballot authorized by the President. An affirmative vote from a majority of the total membership of the Board of Governors shall be required for approval of such resolutions.

Sec. 3. A quorum of ten members of the Board of Governors shall be present to vote on resolutions presented at any meeting. Unless otherwise specified, a majority vote of the Governors present shall constitute approval of a resolution.

Sec. 4. A member of the Board of Governors may not authorize an alternate to act or vote in his stead.

Sec. 5. Vacancies in the offices or on the Board of Governors shall be filled by the Board of Governors until the annual elections of the Society.

Sec. 6. The Board of Governors, when filling vacancies in the offices or on the Board of Governors, shall endeavor to appoint persons who in the aggregate are representative of the various branches or organizations of the industries interested in the activities of the Society to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of such industries.

Sec. 7. The time and place of all except special meetings of the Board of Governors shall be determined by the Board of Governors.

Sec. 8. Special Meetings of the Board of Governors shall be called by the President with the proviso that no meeting shall be called without at least seven days prior notice to all members of the Board by letter or telegram. Such a notice shall state the purpose of the meeting.

BYLAW IV

ADMINISTRATIVE PRACTICES

Sec. 1. Special rules relating to the administration of the Society and known as Administrative Practices shall be established by the Board of Governors and shall be added to or revised as necessary to the efficient pursuit of the Society's objectives.

BYLAW V

COMMITTEES

Sec. 1. All committees, except as otherwise specified, shall be formed and appointed in accordance with the Administrative Practices as determined by the Board of Governors.

Sec. 2. All committees, except as otherwise specified, shall be appointed to act for the term served by the officer charged with appointing the committees or until he terminates the appointment.

Sec. 3. Chairmen of the committees shall not be eligible to serve in such capacity for more than two consecutive terms.

Sec. 4. Standing Committees of the Society to be appointed by the President and confirmed by the Board of Governors are as follows:

Honorary Membership Committee
Journal Award Committee
Nominating Committee
Progress Medal Award Committee
Public Relations Committee
Samuel L. Warner Memorial Award Committee

Sec. 5. There shall be an Admissions Committee for each Section of the Society composed of a chairman and three members of which at least two shall be members of the Board of Governors.

Sec. 6. There shall be a Fellow Award Committee composed of all the officers and section chairmen of the Society under the chairmanship of the Past-President. In case the chairmanship is vacated it shall be temporarily filled by appointment by the President.

BYLAW VI

MEETINGS OF THE SOCIETY

Sec. 1. The location and time of each meeting or convention of the Society shall be determined by the Board of Governors.

Sec. 2. The grades of membership entitled to vote are defined in Bylaw I.

Sec. 3. A quorum of the Society shall consist in number of $\frac{1}{15}$ of the total of those qualified to vote as listed in the Society's records at the close of the last fiscal year before the meeting.

Sec. 4. The annual meeting shall be held during the fall convention.

Sec. 5. Special meetings may be called by the President and upon the request of any three members of the Board of Governors not including the President.

Sec. 6. All members of the Society in any grade shall have the privilege of discussing technical material presented before the Society or its Sections.

BYLAW VII

DUTIES OF OFFICERS

Sec. 1. The President shall preside at all business meetings of the Society and shall perform the duties pertaining to that office. As such he shall be the chief executive of the Society, to whom all other officers shall report.

Sec. 2. In the absence of the President, the officer next in order as listed in Article V of the Constitution shall preside at meetings and perform the duties of the President.

Sec. 3. The seven officers shall perform the duties separately enumerated below and those defined by the President:

(a) The Executive Vice-President shall represent the President, and shall be responsible for the supervision of the general affairs of the Society as directed by the President.

The President and the Executive Vice-President shall not both reside in the geographical area of the same Society Section, but one of these officers shall reside in the vicinity of the executive offices. Should the President or Executive Vice-President remove his residence to the same geographical area of the United States as the other, the office of Executive Vice-President shall immediately become vacant and a new Executive Vice-President shall be elected by the Board of Governors for the unexpired portion of the term.

(b) The Engineering Vice-President shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and co-ordination of the work of these committees.

(c) The Editorial Vice-President shall be responsible for the publication of the Society's *Journal* and all other Society publications.

(d) The Financial Vice-President shall be responsible for the financial operations of the Society, and shall conduct them in accordance with budgets prepared by him and approved by the Board of Governors.

(e) The Convention Vice-President shall be responsible for the national conventions of the Society. He shall arrange for at least one annual convention to be held in the fall of the year.

Sec. 4. The Secretary shall keep a record of all meetings; and shall have the responsibility for the care and custody of records, and the seal of the Society.

Sec. 5. The Treasurer shall have charge of the funds of the Society and disburse them as and when authorized by the Financial Vice-President. He shall be bonded in an amount to be determined by the Board of Governors, and his bond shall be filed with the Secretary.

Sec. 6. Each officer of the Society, upon the expiration of his term of office, shall

transmit to his successor a memorandum outlining the duties and policies of his office.

BYLAW VIII
SOCIETY ELECTIONS

Sec. 1. All officers and governors shall be elected to their respective offices by a majority of ballots cast by voting members in the following manner:

Nominations shall first be presented by a Nominating Committee appointed by the President, consisting of nine members, including a Chairman. The committee shall be made up of two Past-Presidents, three members of the Board of Governors not up for election, and four other voting members, not currently officers or governors of the Society. Nominations shall be made by three-quarters affirmative vote of the total Nominating Committee.

Not less than three months prior to the Annual Fall Meeting, the Board of Governors shall review the recommendations of the Nominating Committee, which shall have nominated suitable candidates for each vacancy.

Such nominations shall be final unless any nominee is rejected by a three-quarters vote of the Board of Governors present and voting. The Secretary shall then notify these candidates of their nomination. From the list of acceptances, not more than three names for each vacancy shall be selected by the Board of Governors and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the name of any voting member other than those suggested by the Board of Governors may be voted for. The balloting shall then take place. The ballot shall be enclosed with a blank envelope and a business reply envelope bearing the Secretary's address and a space for the member's name and address. One set of these shall be mailed to each voting member of the Society, not less than forty days in advance of the annual fall meeting.

The voter shall then indicate on the ballot one choice for each vacancy, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention.

The sealed envelope shall be delivered by the Secretary to a Committee of Tellers appointed by the President at the annual fall convention. This committee shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly-elected officers and governors of the Society shall take office on January 1, following their election.

BYLAW IX
DUES AND INDEBTEDNESS

Sec. 1. The annual dues shall be fifteen dollars ($15) for Fellows and Active members, ten dollars ($10) for Associate members, and five dollars ($5) for Student members, payable on or before January 1, of each year. Current or first year's dues for new members in any calendar year shall be at the full annual rate for those notified of election to membership on or before June 30; one half the annual rate for those notified of election to membership in the Society on or after July 1.

Sec. 2. (a) Transfer of membership to a higher grade may be made at any time subject to the requirements for initial membership in the higher grade. If the transfer is made on or before June 30, the annual dues of the higher grade are required. If the transfer is made on or after July 1, and the member's dues for the full year have been paid, one half of the annual dues of the higher grade is payable less one half the annual dues of the lower grade.

(b) No credit shall be given for annual dues in a membership transfer from a higher to a lower grade, and such transfers shall take place on January 1, of each year.

Sec. 3. Annual dues shall be paid in advance.

Sec. 4. Failure to pay dues may be considered just cause for suspension.

BYLAW X
PUBLICATIONS

Sec. 1. The Society shall publish a technical magazine to consist of twelve monthly issues, in two volumes per year. The editorial policy of the *Journal* shall be based upon the provisions of the Constitution and a copy of each issue shall be supplied to each member in good standing mailed to his last address of record.

Copies may be made available for sale at a price approved by the Board of Governors.

BYLAW XI

LOCAL SECTIONS

Sec. 1. Sections of the Society may be authorized in any locality where the voting membership exceeds twenty. The geographic boundaries of each Section shall be determined by the Board of Governors. Upon written petition for the authorization of a Section of the Society, signed by twenty or more voting members, the Board of Governors may grant such authorization.

SECTION MEMBERSHIP

Sec. 2. All members of the Society of the Motion Picture and Television Engineers in good standing residing within the geographic boundaries of any local Section shall be considered members of that Section.

Sec. 3. Should the enrolled voting membership of a Section fall below twenty, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining that Section, the Board of Governors may cancel its authorization.

SECTION OFFICERS

Sec. 4. The officers of each Section shall be a Chairman and a Secretary-Treasurer. The Section chairmen shall be ex-officio members of the Board of Governors and shall continue in such positions for the duration of their terms as chairmen of the local Sections. Each Section officer shall hold office for one year, or until his successor is chosen.

SECTION BOARD OF MANAGERS

Sec. 5. The Board of Managers shall consist of the Section Chairman, the Section Past-Chairman, the Section Secretary-Treasurer, and six voting members. Each manager of a Section shall hold office for two years. Vacancies shall be filled by appointment by the Board of Managers until the annual election of the Section.

SECTION ELECTIONS

Sec. 6. The officers and managers of a Section shall be voting members of the Society. All officers and managers shall be elected to their respective offices by a majority of ballots cast by the voting members residing in the geographical area of the Section. Not less than three months prior to the annual fall convention of the Society, nominations shall be presented to the Board of Managers of the Section by a Nominating Committee appointed by the Chairman of the Section, consisting of seven members, including a chairman. The committee shall be composed of the present Chairman, the Past-Chairman, two other members of the Board of Managers not up for election, and three other voting members of the Section not currently officers or managers of the Section. Nominations shall be made by a three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final, unless any nominee is rejected by a three-quarters vote of the Board of Managers, and in the event of such rejection the Board of Managers will make its own nomination.

The Chairman of the Section shall then notify the candidates of their nomination. From the list of acceptances, not more than three names for each vacancy shall be selected by the Board of Managers and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the name of any voting member other than those suggested by the Board of Managers may be voted for. The balloting shall then take place. The ballot shall be enclosed with a blank envelope and a business reply envelope bearing the local Secretary-Treasurer's address and a space for the member's name and address. One of these shall be mailed to each voting member of the Society residing in the geographical area covered by the Section, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention. The sealed envelopes shall be delivered by the Secretary-Treasurer to his Board of Managers at a

duly called meeting. The Board of Managers shall then examine the returned envelopes, open and count the ballots, and announce the results of the election.

The newly-elected officers and managers shall take office on January 1, following their election.

SECTION BUSINESS

Sec. 7. The business of a Section shall be conducted by the Board of Managers.

SECTION EXPENSES

Sec. 8. (a) At the beginning of each fiscal year, the Secretary-Treasurer of each section shall submit to the Board of Governors of the Society a budget of expenses for the year.

(b) The Treasurer of the Society shall deposit with each Section Secretary-Treasurer a sum of money for current expenses, the amount to be fixed by the Board of Governors.

(c) The Secretary-Treasurer of each Section shall send to the Treasurer of the Society, quarterly or on demand, an itemized account of all expenditures incurred during the preceding period.

(d) Expenses other than those enumerated in the budget, as approved by the Board of Governors of the Society, shall not be payable from the general funds of the Society without express permission from the Board of Governors.

(e) The Section Board of Managers shall defray all expenses of the Section not provided for by the Board of Governors, from funds raised locally.

(f) The Secretary of the Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

SECTION MEETINGS

Sec. 9. The regular meetings of a Section shall be held in such places and at such hours as the Board of Managers may designate. The Secretary-Treasurer of each Section shall forward to the Secretary of the Society, not later than five days after a meeting of a Section, a statement of the attendance and of the business transacted.

CONSTITUTION AND BYLAWS

Sec. 10. Sections shall abide by the Constitution and Bylaws of the Society and conform to the regulations of the Board of Governors. The conduct of Sections shall always be in conformity with the general policy of the Society as fixed by the Board of Governors.

BYLAW XII

STUDENT CHAPTERS

Sec. 1. Student Chapters of the Society may be authorized in any college, university, or technical institute of collegiate standing. Upon written petition for the authorization of a Student Chapter, signed by twelve or more Society members, or applicants for Society membership, and the Faculty Adviser, the Board of Governors may grant such authorization.

CHAPTER MEMBERSHIP

Sec. 2. All members of the Society in good standing who are attending the designated educational institution shall be eligible for membership in the Student Chapter, and when so enrolled they shall be entitled to all privileges that such Student Chapter may, under the Constitution and Bylaws, provide.

Sec. 3. Should the membership of the Student Chapter fall below ten, or the average attendance at meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

CHAPTER OFFICERS

Sec. 4. The officers of each Student Chapter shall be a Chairman and a Secretary-Treasurer. Each Chapter officer shall hold office for one year, or until his successor is chosen. Where possible, officers shall be chosen in May to take office at the beginning of the following school year. The procedure for holding elections shall be prescribed in Administrative Practices.

FACULTY ADVISER

Sec. 5. A member of the faculty of the same educational institution shall be designated by the Board of Governors as Faculty Adviser. It shall be his duty to advise the officers on the conduct of the Chapter and to approve all reports to the Secretary and the Treasurer of the Society.

CHAPTER EXPENSES

Sec. 6. The Treasurer of the Society shall deposit with each Chapter Secretary-Treasurer a sum of money, the amount to be fixed by the Board of Governors. The Secretary-Treasurer of the Chapter shall send to the Treasurer of the Society at the

end of each school year or on demand an itemized account of all expenditures incurred.

CHAPTER MEETINGS

Sec. 7. The Chapter shall hold at least four meetings per year. The Secretary-Treasurer shall forward to the Secretary of the Society at the end of each school year a report of the meetings for that year, giving the subject, speaker, and approximate attendance for each meeting.

BYLAW XIII

AMENDMENTS

Sec. 1. Proposed amendments to these Bylaws may be initiated by the Board of Governors or by a recommendation to the Board of Governors signed by ten voting members. Proposed amendments may be approved at any regular meeting of the Society at which a quorum is present, by the affirmative vote of two-thirds of the members present and eligible to vote thereon. Such proposed amendments shall have been published in the *Journal* of the Society, in the issue next preceding the date of the stated business meeting of the Society at which the amendment or amendments are to be acted upon.

Sec. 2. In the event that no quorum of the voting members is present at the time of the meeting referred to in Sec. 1, the amendment or amendments shall be referred for action to the Board of Governors. The proposed amendment or amendments then become a part of the Bylaws upon receiving the affirmative vote of three-quarters of the entire membership of the Board of Governors.

16-Mm Sound Service Test Film

Users and manufacturers of 16-mm sound projectors have long had available a comprehensive group of sound test films produced and sold by the Society and the Motion Picture Research Council. Although distribution of these films was not restricted, but on the contrary has been encouraged widely, the order of technical accuracy demanded by the specifications under which they were made forced production costs up so high that their use was, in effect, restricted to professional applications.

Realizing that there was a tremendous need for a more practical type of sound test film, combining on one reel several tests having an order of accuracy commensurate with the test equipment and tools in use by projector service men, the Society set about developing such a film. The result is the recently announced 16-Mm Sound Service Test Film. It includes technical test sections that check the lateral position of the film as it passes the sound scanning beam, the focus of the sound reproducer optical system and the over-all frequency-response characteristic of the projector. There are also three music samples, and one section of dialogue that provide a critical over-all listening test. Together, these several sections will show whether or not poor sound performance is the fault of the projector, and if so, the nature of the trouble being encountered.

Individual projector owners, schools, churches and service shops may now perform a specific series of tests, and by following the instructions that appear on the screen, interpret the test results in terms of repairs or adjustments needed to put the equipment back in good order.

TITLE MUSIC. The title music is a specially recorded orchestral section selected as a subjective test of the frequency range, high- and low-frequency balance, and distortion introduced by the 16-mm projector being tested. If the sound system is correctly adjusted, this section, particularly in the ascending xylophone runs and the high-pitched bell tones, should be clear, crisp and full, without harshness and without quaver.

SOUND FOCUSING TEST. This section is for use in making a quick focus adjustment of the sound optical system and contains 15 ft of square wave, 5,000-cycle track. Maximum loudness of the tone from the loudspeaker is a sufficient indication of correct focus. If correct adjustment cannot be attained in the length of time provided using the normal focus control, it is recommended that a careful shop adjustment be made using Service Type Sound Focusing Test Film, Z22.42, which is 100 ft in length and is supplied with complete instructions for use.

BUZZ TRACK. When this section is run on the projector in correct adjustment, that is when the sound-track scanning light beam is properly positioned and the film does not weave from side to side, no tone should be heard from the loudspeaker. If the scanning beam is too near the edge of the film, a 1000-cycle tone will be audible; or if it is too far from the edge a 300-cycle tone will be heard. Adjusting the guides that position the film laterally should eliminate both tones. The tones will be heard alternately if the film is weaving from one side to the other, and they will both be heard at once if the length of the scanning beam is too great. To remedy either of the last two faults, a shop adjustment should be made using the American Standard Buzz Track Film, Z22.57.

FREQUENCY RESPONSE. This section is a subjective test which permits the listener to make a quick aural evaluation of the frequency response of the projector and its loudspeaker. There are twelve different frequencies ranging from 50 through 6,000 cycles, each of which runs for about ten seconds. A 400-cycle tone precedes the 50-cycle section and also follows the 6,000-cycle section, as a volume-level check.

During reproduction of the first section, the tone control should be set at normal and the volume control adjusted for a comfortable listening level. All tones that follow should be clearly audible and none should be uncomfortably loud. If any of the foregoing conditions is not met, the projector is not operating in a satisfactory manner.

Assuming the buzz track and sound focusing section have indicated correct optical adjustment, failure to reproduce the multi-frequency section properly indicates trouble in the amplifier or associated loudspeaker system. Adjustment and repair of these components require the use of precision instruments and a carefully calibrated multi-frequency test film made in accordance with American Standard, Z22.44.

DIALOGUE. This section is included as an example of good dialogue recording. Sibilants should be clear and crisp, while low tones should be full. With the loudspeaker placed near or directly behind the screen there should be a definite feeling of "presence."

PIANO MUSIC. When this section is correctly reproduced it should give the reverberant effect of being played in a "live" room. The full tonal range should reproduce well, particularly without appreciable waver of sustained notes. Failure to meet this latter requirement indicates varying rate of motion as the film passes the sound scanning beam and the projector should be checked using American Standard 3,000-Cycle Flutter Test Film, Z22.43.

ORCHESTRAL MUSIC. This section should give the effect of being played in a large auditorium having a slight reverberation characteristic. The orchestra should sound well balanced and the volume range should be handled by the projector without the necessity for changing the adjustment of the volume controls. High-level passages should reproduce without distortion while the low-level portions should be clearly audible.

Characteristics of Color Film Sound Tracks

A Report of the SMPTE Color Commission

67th Semiannual Convention

To bring yourself and your company up to date on the technical trends in motion pictures and television, you can do nothing better than attend the 67th Convention of the Society that will be held at The Drake hotel in Chicago from April 24 to 28.

In ten technical sessions, to be held two each day from Monday through Friday, you will hear papers on many subjects including, among others, projection arc lamps, production techniques for television studios, high-speed photography and color. You will also be invited to take part in the informal discussions that follow the presentation of all papers.

HOTEL RESERVATIONS: Rooms have been set aside for all members and their friends who wish to attend. Mr. John Gorte, Office Manager, The Drake, Chicago 11, Ill., will confirm your accommodations promptly if you will mail him the room reservation card you received during the first week of March. If you haven't mailed it, do so without delay to be certain of your accommodations in advance.

TRAVEL: Arrange for your train or plane reservations both to and from Chicago well ahead of time, because week-end travel is particularly heavy in and around Chicago. Your local travel agent will be glad to schedule your trip at least one month in advance.

CONVENTION REGISTRATION: Registration will begin at 9:30 Monday morning, April 24, in the hotel's French Room Foyer. The Registration Desk will remain open during all technical sessions, with luncheon and banquet tickets available from either E. R. Geib or W. C. Kunzmann.

LUNCHEON: A prominent speaker will address the 'Get-Together' Luncheon, scheduled for 12:30 Monday, April 24, in the hotel's Gold Coast Room. To assure seating, tickets should be purchased in advance, and table reservations must also be made with Mr. Kunzmann as early as possible. If you have special requirements, it would be well for you to write him at: National Carbon Division, Box 6087, Cleveland, 1, Ohio.

BUSINESS SESSION: Immediately following the luncheon, all the Society's Voting Members will be asked to attend an official Business Meeting of the Society in the Grand Ballroom to discuss and vote on the proposed new Society Bylaws that are published on p. 367 of this JOURNAL. This is the only business scheduled for the meeting, and since voting doubtless will be concluded promptly, the first technical papers of the Convention will be presented without delay.

COCKTAIL HOUR AND BANQUET: Wednesday evening is the time for frivolity. Bill Kunzmann will serve as host to all members and guests at the Cocktail Party which begins at 6:45 in the French Room and the informal banquet scheduled to start at 8:00 o'clock in the Gold Coast Room. There will be music, dancing,

entertainment and fun for all. Tickets for the banquet should be purchased early. Table reservations must be made with Mr. Kunzmann at the Registration Desk before Wednesday so that members may be assured of places for themselves and their guests.

LADIES' ACTIVITIES: For the wives and guests of members who plan to be in Chicago during convention week, Mrs. G. W. Colburn, Convention Hostess, and the members of the Ladies' Reception Committee have arranged a program that will prove to be both interesting and entertaining. The details of these plans will be discussed at the Ladies' Registration Headquarters in Parlor H by members of the Ladies' Reception Committee, who will be on hand daily.

RECREATION: Members and their guests who register will receive complimentary passes for the week to several de luxe motion picture theaters in Chicago. Chicago has much to offer in the way of places of historical interest and other attractions that will be described at the Registration Desk.

PLAN TO ATTEND: Bring your friends and make a successful week of this – the 67th Semiannual Convention.

Society Announcements

Student Chapter

The Student Chapter of the Society at New York University was formally established by action of the Board of Governors on January 31, 1950. This is the second Student Chapter. The first was organized at the University of Southern California and is presently under the Chairmanship of Algernon Walker.

Formation of a New York University Chapter was first proposed to the Society on November 9, 1949, by William F. Boden, a student in the Motion Picture Dept., representing 15 applicants for Student membership. Subsequently, they petitioned the Board of Governors for authorization to form a Student Chapter within the limitations established under the Bylaws of the Society.

After duly considering the petition, which had been endorsed by Professor Robert Gessner, Chairman of NYU's Motion Picture Dept., the Board of Governors voted to authorize formation of the Chapter, and extended to all Chapter members its enthusiastic welcome.

The Chapter Officers are: William F. Boden, Chairman; Gerald I. Rosenfeld, Secretary-Treasurer; and Professor Gessner, Faculty Adviser.

New Sustaining Members

The Society is always pleased to welcome additions to its list of Sustaining Members. Each new one who joins provides additional financial support needed to help carry out the many projects assigned to engineering committees and to continue the ambitious publications program being undertaken. In addition, the continued increase of sustaining support is a measure of proof that the Society's contributions to the fields that lie within the area of its technical scope are both valid and effective.

The Society is pleased to acknowledge these Sustaining Memberships, received during the past month: Blumenfeld Theaters, DuArt Film Laboratories, Inc., Hallen Corp., National Screen Service and Producers Service Co.

Film Decomposition Tests

In the paper that begins on p. 268 of this JOURNAL, Cummings Hutton and Silfin point out the serious losses that may result from decomposition in storage of cellulose nitrate motion picture film. Much of this potential loss could no doubt be avoided if a reliable test for future storage life were applied to films now being stored for commercial and archival purposes. No such test is now used regularly in the United States, but recently the attention of film librarians has been directed to two such tests developed in England, under the auspices of the British Government's Chemical Research and Development Establishment and the Department of the Government Chemist. In Report No. 2/R/48, "The Surveillance of Cinematograph Record Film During Storage," by G. L. Hutchison, L. Ellis, and S. A. Ashmore, the authors described a rather extensive investigation of the stability of film in storage and outlined the details of two test procedures which they have found useful. Further information concerning the use of these tests and the results obtained may be secured from the British Film Institute, 164 Shaftesbury, London, England. This is a government department similar to the U.S. National Archives.

So that the SMPTE's Preservation of Film Committee may have the benefit of a number of points of view concerning both the value of such tests generally and the advisability of further committee study in this direction, a brief summary of this British Report and an outline of the test methods are described immediately below. Comments and recommendations should be addressed to James W. Cummings, Chairman, SMPTE Preservation of Film Committee, The National Archives, Washington 25, D.C.

SUMMARY

"The deterioration of nitrocellulose base cinematograph film on prolonged storage is brought about by a slow but progressive decomposition of the nitrocellulose. The changes occurring are complex but it seems clear that the gelatine on the film acts as a stabilizer and accordingly suffers deterioration which involves loss of the contained silver image at about the same time that the film becomes sticky. This stage is the end of the useful life of the film, and as such film cannot be duplicated it represents a total loss of record.

"Two tests, based on methods of known value in the examination of nitrocellulose explosives, have been developed whereby it is possible to anticipate the end of the useful life of a film. The results of these tests allow sufficient time for a film to be duplicated while still in good physical condition.

"Using the two tests referred to in the above paragraph a scheme of surveillance and sentencing of stored films has been devised.

"Since the useful life of a film is well ended before conditions favorable to spontaneous inflammation arise, it is clear that danger from this source can now be avoided.

"The results of this investigation are clearly applicable in principle to all stored cinematograph film having a cellulose nitrate base."

Two recommended tests for predicting the future condition of nitrate film in storage are the Alizarin Red Heat Test and the Micro-Crucible Test. These are described briefly below:

ALIZARIN RED HEAT TEST

In this test a small punching of the film of approximately 6 mm diameter and weighing 7 mg is heated in a glass tube in which is suspended an alizarin red test paper moistened with a solution of glycerine in water. The tube is heated at a temperature of 134 C and the time noted for the development of acid vapors as indicated by a color change in the test paper.

1. Apparatus

(a) Glass tube closed at one end and approximately 90 mm in length and 9 mm internal diameter is fitted with a stopper 60 mm in length and of such a diameter that when covered with one thickness of test papers makes a close sliding fit in the tube. 45 mm of the stopper should then be in the tube.

(b) A cylindrical double-walled copper air bath, 100 mm deep and 100 mm in diameter. The metal lid is lagged with asbestos composition 8 mm thick and contains a central hole to take a thermometer and six holes, of 12-mm diameter, suitably arranged to take six testing tubes. The outer jacket of the bath is fitted with a reflux condenser.

(c) A supply of rubber rings to give convenient support to the tubes in the air bath.

(d) A supply of large size filter papers (Whatman, No. 2).

2. Preparation of the Test Paper

This is conveniently prepared by impregnating a sheet of filter paper with a 0.1% solution of alizarin red indicator in water to which has been added 2 ml of 2 *N* ammonia per 100 ml. The solution is allowed to drain off and the edges of the paper are subsequently discarded. The paper may then be air dried but should be further heated for 10 min in the steam oven before use, to drive off any traces of free ammonia.

3. Method

The outer jacket of the bath is charged with about 20 ml of pure xylene and heat is applied by means of a small gas burner. When temperature conditions are steady the thermometer should read 134 C.

In the meantime six tubes, as described at (a) under Apparatus, are prepared for test. Into each is placed a punching of the film under test, the punching being 6 mm in diameter and weighing about 7 mg. A strip of test paper is cut to such a width that when wrapped around the stopper the whole of the latter is effectively covered without any overlap which would spoil the snug fit in the tube. The test paper is then moistened with a 50% solution of glycerine in water. Each tube is fitted with a rubber ring, the position of which is adjusted so that the part of the tube contain-

ing the test paper is wholly outside the bath.

With all tubes in position in the bath the temperature and time are noted. The tubes are kept under constant observation, if necessary for rather more than one hour.

The color of the test paper prepared as described is maroon, which, in the presence of acid vapors, is either bleached or becomes a pale yellow. The change is well marked and readily observed: for the purposes of this test, the time in minutes required for a positive result is taken when the lower edge of the paper is bleached or changed in color to a distance of approximately $\frac{1}{8}$ in.

Note 1. The apparatus described can suitably be increased in size so that more than six samples can be tested at one time.

Note 2. If a tube is removed after test while the other tubes are in position, the vacant hole must be closed with a cork or bung.

MICRO-CRUCIBLE TEST

This test involves the determination of the loss in weight of a punching of cinema film when heated in a small porcelain crucible in a ventilated oven maintained at 100 C.

The crucibles are of 1 ml capacity and are obtainable from Royal Worcester Porcelain Co., or indirectly through laboratory supply firms.

A disc of film of approximately 0.25-in. diameter and weight about 7 mg is punched out of the film in question and transferred to the crucible weighed to the nearest 0.01 mg. The combined weight of crucible and film is then determined accurately, also to 0.01 mg, and the weight of film found by difference.

The crucible and film are then heated in a ventilated oven maintained at 100 C and the combined weight determined at 168 hr and 300 hr. The loss in weight is then calculated as a percentage on the original weight of the film.

RESULTS		*SENTENCE*
Alizarin Red Heat Test	*Micro-Crucible Test* (after 168 hr)	*Retest after:*
60 min and over	—	2 yr
Under 60 min but not under 30 min	—	1 yr
Under 30 min but not under 10 min	Under 10%	6 months
	10% and over	Copy and destroy
Under 10 min	—	Copy and destroy

Meetings of Other Societies

Institute of Radio Engineers, Cincinnati Section, Spring Technical Conference on Television, April 29, Cincinnati, Ohio

Institute of Radio Engineers, Technical Conference, May 3–5, Dayton, Ohio

Armed Forces Communications Assn., Annual Meeting,
May 12, New York, and Long Island City
May 13, Fort Monmouth, N.J.

Acoustical Society of America, Spring Meeting, June 22–24, State College, Pa.

Illuminating Engineering Society, National Technical Conference, August 21–25, Pasadena, Calif.

Engineering Committees

Theater Television

On February 14, the Society transmitted to the Federal Communications Commission a formal reply to the Commission's Public Notice of January 11 which outlined its plans for a hearing on allocations and rule making for a theater television service. The ten points at issue in the present controversy, as stated by the Commission, were published on p. 237 of the February JOURNAL. The Society's reply read as follows:

"Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington 25, D.C.

"In the Matter of

Allocation of Frequencies and Promulgation of Rules and Regulations for a Theater Television Service — Docket No. 9552

NOTICE OF APPEARANCE

"In accordance with Provision 7 of Public Notice No. 45051 of the Federal Communications Commission, dated January 11, 1950, and dealing with a hearing on Theater Television, the Society of Motion Picture and Television Engineers hereby files its written appearance in this proceeding, and gives notice that it will appear through its appointed representatives. They will present evidence on the issues specified in the aforementioned notice of hearing issued by the Commission upon such data, and at such time and place as may be selected by the Commission.

"Submitted for the Society of Motion Picture and Television Engineers by

(Signed) E. I. SPONABLE
President"

Color

The commercial success over the last ten years of a number of different processes for motion picture release printing in color has been a substantial boon to the industry but has simultaneously introduced several very practical problems that will undoubtedly remain with us for some time to come. Limited familiarity with the language of color as a general branch of physics or as a highly specialized branch of motion picture engineering is an obstacle to many engineers and technicians who encounter these color systems in their daily work. In research or film processing laboratories where the nomenclature is better understood, the lack of uniform methods of measurement or specification complicates the already difficult problem of drawing significant comparisons between competitive processes. Commercial applications which involve the use of more than one manufacturer's product at succeeding steps in the complete process are made exceedingly complex and for the same reason the recording, duplicating and reproducing of photographic sound tracks on color films are made many times more difficult than is the case with familiar black-and-white emulsions.

To shed some additional light on this latter problem, a Color Subcommittee, under the Chairmanship of Lloyd T. Goldsmith, has prepared a tabulation of the characteristics of sound tracks produced on commercial 35- and 16-mm color print processes. The table appears on p. 377 of this JOURNAL.

Not only manufacturers and users of sound reproducing equipment, but also film laboratory technicians will find this table of real value. Reprint copies on heavy paper have been prepared and will be supplied free of charge by the Society to all who wish them. Requests for copies or comments on the tabulation should be addressed to Bill Deacy at Society Headquarters.

An early issue of the JOURNAL will carry a more extensive contribution to the available literature on color motion pictures. This will be in the form of a report on the "Principles of Color Sensitometry," prepared by the Color Sensitometry Subcommittee under the Chairmanship of Carl F. J. Overhage. This report, which has been in work for nearly a year, is now completed and in manuscript form it amounts to nearly 150 pp.

Film Dimensions

Methods of producing 16-mm release prints in large quantity through the use of 32-mm perforated films have been adopted widely in the United States during the last decade. Experience gained over this period has resulted in the gradual development of uniform practices in preparation of negative picture and sound material, in printing the release positives and in slitting after processing to produce the 16-mm prints for projection. Work was begun in 1948 on standards for the special films thus used. Formal proposals for the standardization of two 32-mm films and one 35-mm film, 32-mm perforated, were published for a period of trial and criticism in the February, 1949, JOURNAL. Shortly after publication, a question arose concerning commercial slitting tolerances of 32-mm raw stock but on further investigation raw stock was found to be within the limits published in the proposed standards. As a result objections to the original proposals were withdrawn and two of them, previously approved by the Standards Committee, have now been forwarded to the ASA Sectional Committee on Motion Pictures, Z22. The third, covering the Dimensions of 35-mm film with 32-mm perforations, had not previously been sent to the Standards Committee, so is now out for their consideration. When the action of the Standards Committee is completed, this proposal will also be submitted to the Sectional Committee.

Book Review

Introduction to Theoretical and Experimental Optics, by Joseph Valasek

Published (1949) by John Wiley and Sons, 440 Fourth Ave., New York 16. 429 pp. + 6 pp. appendix + 4 pp. "Answers to Problems" + 4 pp. bibliography + 10 pp. index. 44 illus. $5\frac{3}{8} \times 8\frac{3}{8}$ in. Price $6.50.

Publication of a new textbook of optics is a rather rare event these days when general attention is diverted to the more spectacular topics which abound in nuclear physics and electronics. A good general reason exists, therefore, to welcome this book. This is, however, not the only reason, as the book has its own

merits and it constitutes a valuable contribution to the fundamental optical literature.

The purpose of this book is to give the college student a working knowledge of the extended field of optics. Accordingly, the text covers in its four parts geometrical optics, physical optics, radiation and spectra, and a series of laboratory experiments under the heading of experimental optics. The first three parts are divided into 21 chapters accompanied by problems.

The presentation of the subject matter is well balanced and necessarily condensed, for it would not be possible to cover all the branches of optics and some closely related subjects in one handy volume. As was noted by the author and the publishers, some subjects (X rays, photographic optics, and ophthalmic lenses) are treated in greater detail than is customary in general textbooks of optics. This deviation from the usual is not objectionable to the reviewer. Although the reviewer cannot offer definitive rules as to what should be included and what may be excluded from a college textbook, he feels that no textbook should ignore the phenomena and objects with which we are in practically everyday contact. Indeed, it is rather discouraging to meet students who are conversant with the Kerr, Zeeman, Raman and other "effects," but have very little to say about their own spectacles or their photographic lenses. Let us hope that Prof. Valasek's students will be well acquainted with both laboratory and everyday aspects of optics.

Following this thought, the reviewer would have been pleased had the author at least briefly touched also the following subjects: medical and industrial radiology, biological effects of radiation, condensing and projection systems, anti-reflection films, interference filters, and phase-contrast microscopy. It is particularly difficult to justify the omission of the last three subjects which are now in the limelight of optical engineering.

The reviewer is disturbed by the fact that no recognition is given in the book to the current standardization efforts in the field of optics. Thus, while the term "equivalent focal length" has been widely used and recently sanctioned as standard by the American Standards Association (Z38.4.21—1948), it is not even mentioned in the book. It is beside the point whether or not the term is satisfactory (the reviewer is of the opinion that the "equivalent" is superfluous and misleading), as perhaps no terminology can satisfy everybody. The fact is that a strong demand exists for standardization of terms, definitions, and procedures in optics, and that a serious effort is being made, under the sponsorship of the Optical Society of America and of other organizations, to satisfy the demand. This effort will be in vain if our educational institutions do not teach the younger generation to appreciate standardization and to adhere to it. It will also be disheartening to the younger generation to discover, for example, that, while knowing the H-D speed, the Schneider number, the DIN system, and the Weston rating, they know nothing about the American Standard Speed and the American Exposure Index (Z38.2.1—1947), which are not mentioned in this book.

The book is not intended as an engineering manual. Still it may be very useful as a source of basic information to any engineering or research group concerned with optical problems. The well-selected bibliography at the end of the book adds considerably to its reference value.

DR. K. PESTRECOV
Bausch & Lomb Optical Co.
Rochester 2, N.Y.

Letter to the Editor

In "Twenty-Lens High-Speed Camera" by Charles W. Wyckoff, in the November, 1949, JOURNAL, some acknowledgments were not mentioned. The design and construction of the twenty-lens camera was carried out under the direction of Mr. Newell T. Partch who was then located at the David Taylor Model Basin. The camera itself was built at the Naval Observatory. The optical calculations were done by Dr. A. I. Mahan of the Naval Ordnance Laboratory. Mr. Wyckoff served as a consultant on the mechanical and electrical elements of the camera. Figures 6, 7 and 8 appearing in Mr. Wyckoff's paper were the result of some of the previously mentioned optical calculations. The lens chosen for this camera was not a standard Navy lens as suggested by Mr. Wyckoff. It was a simple achromatic doublet, whose characteristics were all carefully evaluated so that its performance would be known before inserting it in such a camera. Such achromatic doublets of the speed used here cannot be used at a field angle of 13° with good results. Nevertheless, this choice was made rather early to keep the cost of the first model of the camera down, with the result that the image quality deteriorated at the edge of the field even when the lens was stationary.

A. I. MAHAN
U. S. Naval Ordnance Laboratory
White Oak, Silver Spring 19, Md.

Section Meetings

Atlantic Coast

"High-Speed Motion Pictures" will be the subject of the Atlantic Coast Section Meeting, scheduled for 7:30 P.M., Wednesday, March 22, in the Western Union Auditorium at 60 Hudson St., New York City. John H. Waddell, Chairman of the Society's High-Speed Photography Committee, is to be a speaker.

Dr. Dirk Reuyl, Ballistics Research Laboratory, Aberdeen Proving Ground, Aberdeen, Md., will speak on "Optical Instrumentation for Guided Missiles."

Central

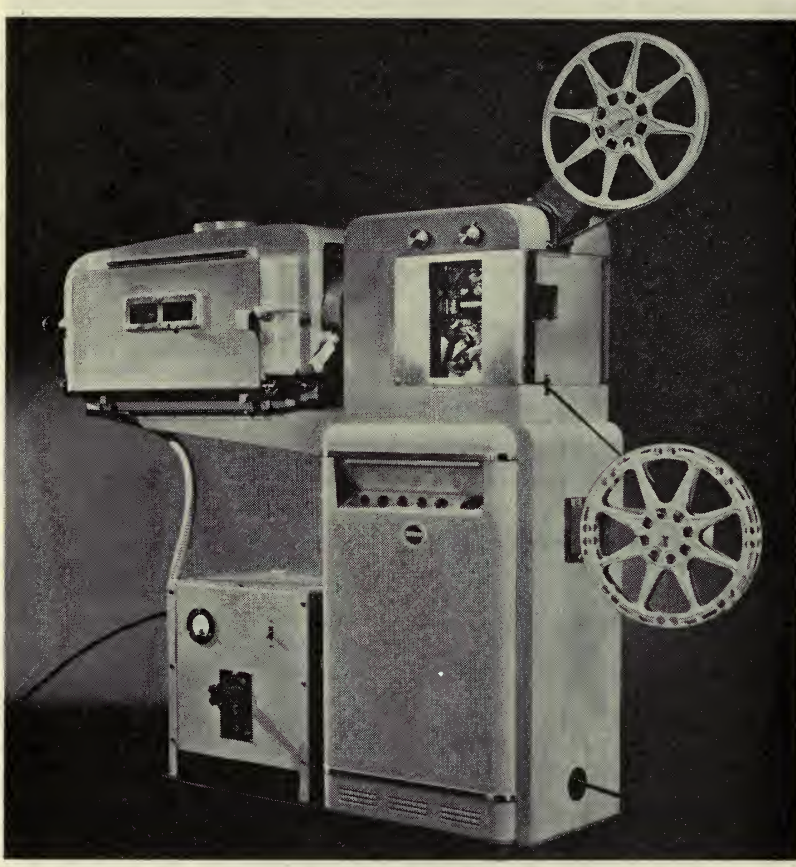
Two papers originally reported in February as being planned for presentation at the February 17th meeting of the Central Section are actually scheduled for the meeting on Thursday, March 16. The Section meets at 8:00 P.M. in the Western Society of Engineers' Auditorium, 84 East Randolph St., Chicago. The first paper is "A New Amplifier Design" by Mr. Frank McIntosh. The second paper, in two parts, describes the new DuPont Type 275 Color Release Positive Film. "Structure and Properties" will be described by Dr. A. B. Jennings, while "Printing and Processing" will be covered by Dr. J. P. Weiss.

Pacific Coast

On Tuesday, March 28, members of the Pacific Coast Section will be guests of the Eastman Kodak Company. They have been invited to attend the first 'open house' tour of the Kodachrome Cine-Processing Laboratory, 1017 No. Las Palmas Ave., Hollywood, Calif.

New Products

Further information concerning the material described below can be obtained by writing direct to the manufacturers. As in the case of technical papers, publications of these news items does not constitute endorsement of the manufacturer's statements nor of his products.



The Eastman 16-Mm Projector, Model 25, just announced by Eastman Kodak Company, has been developed to fill the need for a projector of professional caliber.

Engineered with performance and long operating life as the major design objectives, this projector introduced a number of outstanding features. An 8-frame intermittent sprocket is driven by a synchronous motor interlocked but mechanically independent of a second motor that drives the film transport sprockets and the shutter. A geneva star gives intermittent film motion but is unconventional in that it is driven through a unique two-stage acceleration movement, which increases the ratio of sprocket speed to motor speed at the moment of film pull-down. This gives extremely high acceleration of the intermittent sprocket during the work period of its operating cycle. Shutter efficiency is therefore high.

With two interruptions per frame, the shutter has a transmission of 59%. Individual motors are used to drive the film take-up and rewind reels.

Either carbon arc or 1,000-watt tungsten lamps may be used. When tungsten lamps, which burn base up, are used, a dual lamp turret allows a stand-by lamp to be moved into position in the event of a burn-out.

The sound scanning drum is driven by the film while a magnetically damped stabilizer holds the flutter content to 0.2% rms.

The projector base houses an illuminated control panel and an Altec Lansing amplifier, with tone and volume controls as well as a switch for phonograph or microphone input.

The projector is available, equipped for 115-volt, 60-cycle, a-c operation, and with either the Altec-Lansing Model 800 or the Model 604-B speaker.

"Permanent and lengthy 'on-the-spot' sound recordings" is the lead of the release accompanying this photo from the Miles Reproducer Co., Inc., 812–814 Broadway, New York 3, N.Y. The equipment is described in part as follows: The "Walkie-Recordall" weighs only 8 lb and is enclosed in an inconspicuous carrying case, measuring only 4 × 8 × 10 in., which conceals the identity of a recorder. It is designed to make permanent and continuous recordings, with a concealed microphone, of lengthy conversation of near-by and distant voices, while standing, walking or riding on trains, autos or planes.

Recording is reported to be noiseless, "thus no one is aware that conversation is being recorded," and the operator is said to need to give only the attention required to throw a silent, hidden and external switch to "On" position. It is powered by small flashlight cells and by a miniature "B" battery, both of standard type.

The manufacturer suggests that, in addition to some other, perhaps more obvious, uses "Walkie-Recordall" may be a boon in bolstering salesmen's potentialities: (1) through the aid of recorded expert sales talks to be played back to customers and (2) through reviewing and evaluating an entire day's actual conversation between a salesman and his customers.

SMPTE Officers and Committees: The names of Society Officers and of Committee Chairmen and Members are published annually in the April issue of the Journal. Changes and corrections to these listings are published in the September Journal.

Employment Service

POSITIONS WANTED

Project Engineer: Mechanical engineering graduate experienced in designing from specifications; optical instruments, precision cameras, mechanical servo, and gear or 3-bar computers, analytical work in stress and vibration. R. A. Barbera, 663 Ovington Ave., Brooklyn 9, N.Y.

TV and Motion Picture Engineer: 3 yr experience in motion picture engineering and research at Philips Physical Laboratories, Eindhoven; 6 yr as TV-Director, same firm; 3 yr as Director of Decca plant in Belgium. Desires assignment in any part U.S.A. Highest qualifications and references U.S. firms. Write Fernand Beguin, c/o Mr. Marc Albanese, 416 Madison Ave., New York 17.

In technical phase: Motion picture or still photography. 4 yr experience in research, development, and testing, both color and b & w films. Graduating from M.I.T. June, 1950. Member, SMPTE. W. A. Farmer, 141 Grand Ave., Rochester 9, N.Y.

Cameraman-Director: Currently employed by internationally known producer, desires greater production opportunities. Fully experienced 35- and 16-mm, color, b & w; working knowledge editing, sound, and laboratory problems; administrative experience. Top references and record of experience available. Write P.O. Box 5402, Chicago.

Cameraman: Trained with practical experience in 16-mm and 35-mm equipment & technique with prominently successful men in the industry. Thoroughly familiar with B & H Standard, Mitchell, Eyemo, & Filmo cameras, Moviolas, etc. Thorough knowledge & experience script-to-screen production technique: directing, editing, photography, film evaluation, production, treatments, shooting-scripts, small budgets, documentary & theatrical production. Go anywhere. Age 33. Top industry & character references furnished confidentially. Anxious for position where ability, sincere interest and creativeness offer opportunity. Active Member of SMPTE. Write Milton L. Kruger, R.F.D. 1, Ridgewood, N.J.

SMPTE HONOR ROLL

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased.

Louis Aimé Augustin Le Prince
William Friese-Greene
Thomas Alva Edison
George Eastman
Frederic Eugene Ives
Jean Acme Le Roy
C. Francis Jenkins
Eugene Augustin Lauste
William Kennedy Laurie Dickson

Edwin Stanton Porter
Herman A. DeVry
Robert W. Paul
Frank H. Richardson
Leon Gaumont
Theodore W. Case
Edward B. Craft
Samuel L. Warner
Louis Lumiere
Thomas Armat

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The Eidophor Method For Theater Television

By E. LABIN

Federal Telecommunication Laboratories, Inc., Nutley, N.J.

Summary—The paper considers briefly some system aspects of theater television. The most important single technical problem of theater television remains the method used for large-screen projection. A new system, developed in Switzerland, using a special electromechanical accumulation process is described briefly. It gives projection on full-size screens with ordinary lighting. The system is still in the stage of early development, but has already proven quite promising.

Conceptions of how theater television will be used are not yet clearly settled. This is partially due to the limitations of the available technical tools, and partially to the difficulties of understanding how theater television will fit in with the normal movie programs.

Figure 1 represents a possible network for theater television. It is set up of urban, or local, networks, interconnected through long distance communication links. In each local network there would be one or more centers. The pictures originating at special studios in the city (stadiums, theaters, nightclubs, or perhaps as received from broadcast studios) are received in the local center after transmission through local telephone facilities, or, more likely, through short range microwave links. In this television distribution center, the pictures may be recorded on films, or may be rerouted immediately to the various theaters in the city and may also be sent through long distance networks to another city. In other words, the center operates like a telephone central office, receiving the messages from various points and retransmitting them to the customers. In a city where numerous theaters are grouped company-wise, it may be imagined that each company would have one central office of this type. In other cities, one central office may operate as a sort of limited common carrier for various theater owners. The long distance intercity links may, in turn, be operated directly by theater owners or may be facilities rented from a common carrier company.

The technical tools for setting up a network of the type described

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in Fig. 1 can be grouped in three main categories: transmission, pickup or camera, and projector. The transmission problems can be solved with known methods and it is now possible to equip, with microwave links or coaxial cables, both the local and the long distance networks. While continuous progress is still to be expected in the design of improved cameras, it is well known that cameras are already available with excellent sensitivity. The situation concerning projectors is not quite as clear. Two systems have been put in experimental operation: the intermediate-film method and the direct-projection method using cathode-ray tubes. Another direct-projection method has been developed at the Polytechnical Institute of Zurich, Switzerland, and has been demonstrated successfully in experimental form.

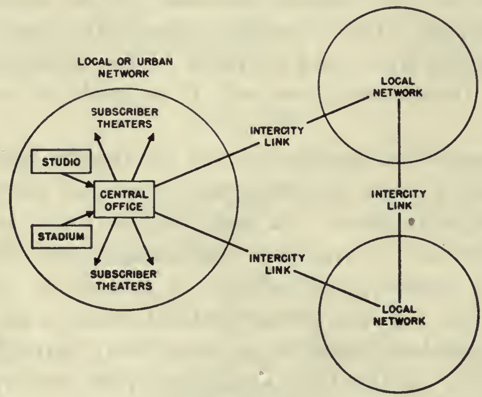

Figure 1.

The main purpose of this paper is to describe the Swiss system. I want to make it quite clear that I have no direct connection with the development of this system. That was done entirely at the Polytechnical Institute of Zurich under the direction of Professor Fischer, at the beginning of the project.[1] Since Professor Fischer's death in 1948, the project has been continued under the very able direction of Professor Baumann. I am reporting on this system at the request of Mr. D. E. Hyndman, Chairman of the SMPTE Theater Television Committee. The only justification for me to report about this system is that I saw it in operation last year in Zurich and I have taken a great interest in these developments. This paper is developed from

material prepared by Dr. H. Thiemann,[2] who is Professor Baumann's assistant and is in charge of this development in Zurich. It is through Dr. Thiemann's courtesy that I have been authorized to illustrate this paper.

If the network conception, briefly described above, is correct, both methods of theater projection, by the intermediate film or through direct projection, are necessary. At the central station office the intermediate-film process is obviously an indispensable element. A permanent record is required for retransmission to the various subscribers at convenient times. On the contrary, at the subscriber's theater there is no need for recording and therefore a direct-projection system is probably the most desirable solution. So far, the only practical solution for direct projection is to use a powerful cathode-ray tube.

How much power do we have to concentrate in the electron beam in order to illuminate the theater screen properly? For a screen of 18 × 24 ft with a luminance of 10 foot-lamberts assuming reflection conforming to Lambert's law with a coëfficient of 0.7, the amount of light flux required is 6,000 lumens on the screen. If this power is projected through a refractive optical system which would have an over-all efficiency of 3%, the source would have to supply 200,000 lumens. With reflection-projection systems of the Schmidt type, one can increase the over-all efficiency to 30% and therefore the light to be supplied by the source would have to be 20,000 lumens. If the transformation from electron beams into light could be done without any loss and if that transformation could take place at the wavelengths for which the eye is most sensitive, 620 lumens would correspond to one watt in the electron beam. The power required in the electron beam would therefore be 30 watts for a transformation efficiency of 100%. The transformation efficiency is actually not more than 1% or 2%, being the product of the spectral efficiency and of the energetic efficiency. The spectral efficiency is of the order of 10% because the light produced by the electron beam is not at the wavelength for which the eye is most sensitive. The energetic efficiency of the transformation from electrons to light quanta is also of the order of 10%, resulting in a final efficiency of 1%, or perhaps 2%.

Finally, the power required in the electron beam is of the order of 3 kw. Present-day cathode-ray tubes do not handle such large amounts of power in the beam. One is, therefore, obliged to cut corners to accept a lower screen brightness, or to try to increase the re-

flection coefficient of the screen by using directive screens, or to use smaller screens.

In all cases, for large screens one has been led to the Schmidt projection system because of its great effective aperture but this system has some limitations, the most disturbing one being that the distance between the projection optics and screen cannot be increased without requiring an extreme mechanical accuracy in the projection system. Present-day practice does not allow a throw as great as the one normally used in theaters and therefore the projector cannot be installed in the normal projection booths. Improvements in cathode-ray tube projectors can be expected, but the figures quoted above show that, at best, one could hope to catch up with present-day practices in movie theaters; but the tendency is for more light and larger screens. The cathode-ray projection scheme has enough limitations to justify an attempt to look into the possibility of developing another competitive method. The fundamental philosophical objection one could raise against the cathode-ray system is that light is generated by the electron beam in the cathode-ray tube and is also controlled in the cathode-ray tube itself. Many proposals have been made in the past, based on the general idea that the light energy will be supplied from a source, such as a projection lamp, and that the intensity of the light which reaches the screen will be controlled by some independent modulation device. As far as we know, none of these proposals has been actually made to work satisfactorily, except the system using the eidophor control of Professor Fischer.

The principle of the system can best be understood with reference to Fig. 2. The light from an arc is projected on the eidophor and the surface of the eidophor itself is projected on the screen. Between the light source and the eidophor there is a slit system (or Schlieren optics), and a second one is located between the eidophor and the screen. The eidophor, which represents the control element, is a thin layer of viscous liquid deposited on a very thin metallic electrode which is transparent to the light beam. The eidophor is mechanically deformed by electrostatic forces resulting from charges which are deposited on the surface by an electron beam hitting the eidophor at a certain angle. The charge produces electrostatic stresses, and the corresponding deformation of the surface, together with the two series of slits, makes it possible to control the light flux.

The theory of the system is based on the assumption that actual diffraction with phase coherence takes place when the light crosses the

eidophor. Figure 3 represents a simplified hypothetical case where one slit only is used instead of a number of bars. In the absence of corrugation on the eidophor surface the lens forms a single image of the lower slit in the plane of the "picture slits." When regular corrugations are present additional secondary images are formed by diffraction, as shown in Fig. 3, in a manner similar to the secondary images obtained from familiar diffraction gratings. The secondary images are displaced by an angle B which depends only upon the wavelength of the light used and the period of the corrugation on the surface of the eidophor.

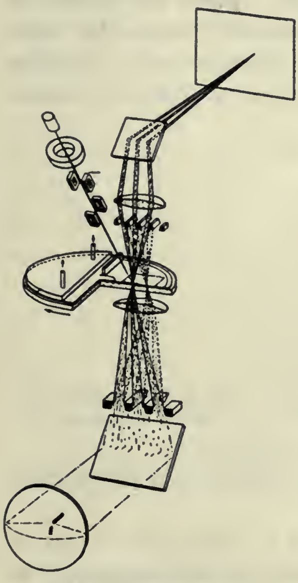

Fig. 2. Large screen television projector.

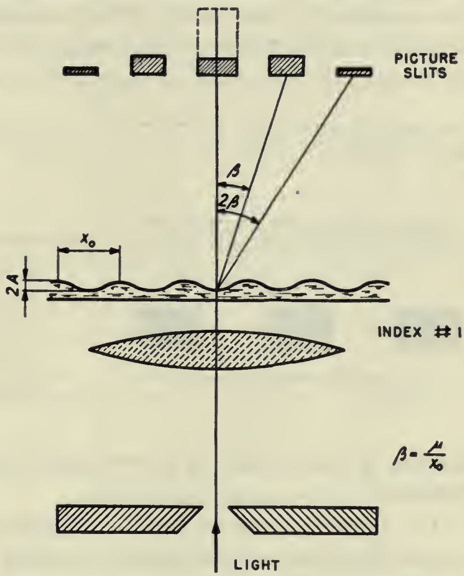

Fig. 3. Diffraction through control grids.

The distribution of light intensity in the secondary images determines the efficiency of the light control which can be achieved in this manner. This light distribution can be calculated and it can be shown that the zero order or original image can be extinguished completely while most of the light flux is shifted into the secondary images. Normally, the secondary images of the first order only are used. The study of the single slit arrangement of Fig. 3 for various forms of deformations of the eidophor surface (sinusoidal, triangular, rectangular, etc.) leads to a certain number of light control curves. A similar

study has been conducted for the extreme opposite theoretical case where an infinite number of slits are used.

From the theoretical curves thus obtained a choice of the optimum number of slits and of their geometric configurations has been made corresponding to the type of deformation occurring in a television picture. For a complete analysis of this phenomenon, which would go far beyond the limits of this presentation, the reader is referred to the original paper of Dr. Thiemann.

Figure 4 shows one possible arrangement. When the surface of the eidophor is flat, the slits are so arranged that no light is transmitted; this, therefore, corresponds to a black picture. When the surface of the eidophor is deformed with a sinusoidal undulation, the total amount of light transmitted corresponds to a white picture. A series of black-and-white lines in the picture would correspond to a defor-

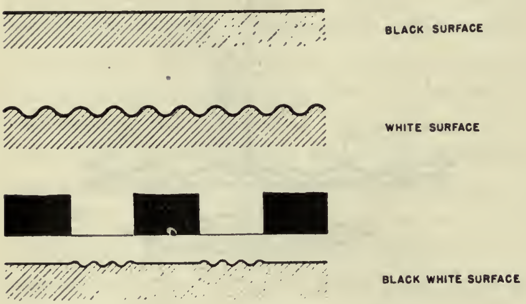

Fig. 4. Deformations on the eidophor.

mation of the surface of the eidophor which would be a flat portion followed by an undulated portion.

The period of the undulation required for a white picture has, of course, to be smaller than the duration of one picture element. In order to generate the deformation required on the eidophor, the electron striking the eidophor has to be modulated by the video signal. One possible method would be to modulate the beam intensity with a high-frequency carrier. For a white picture, the carrier would have the full amplitude and for a black picture the carrier would be entirely suppressed. This method of modulation is not the one that has been finally chosen because, the modulation curve not being fully linear, any intensity modulation is connected with some rectification. This rectification gives rise to charges on the surface of the eidophor. The charges, in turn, generate a constant deformation of the liquid surface and, therefore, an image once registered remains on the sur-

face in more or less a rudimentary form for a considerable time. In order to eliminate this cause of disturbance, a different kind of modulation has been chosen. The intensity of the beam remains constant but the scanning speed in the direction of the line is varied to conform to the video signal.

The video signal is still superimposed on a carrier which will act on the deflection of the electron beam through additional deflection plates. (The deflective voltage required is 1 volt.) In order to generate the desired deformations of the eidophor within our picture element the spot size of the electron beam shall be no more than one-quarter of the desired local period of the deformation which in turn shall be close to one-half the size of the picture element. This leads

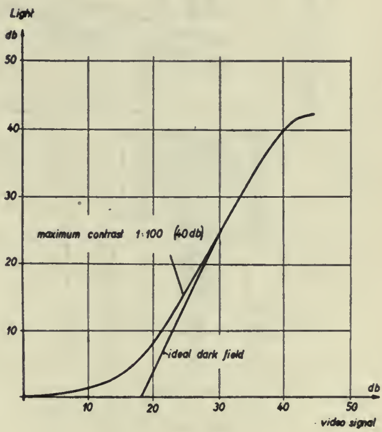

Fig. 5. Light control curve of the Schlieren optical system.

to very fine cathode-ray beams (the spot size is .001 in. in the direction of the scanning lines) and has represented one of the difficult problems of the system.

Figure 5 shows the modulation curve which can be actually achieved. The variation of light intensities is shown in a logarithmic scale *versus* the video input signal. In the curve shown, the effect of stray light has also been taken into consideration. The great importance of this stray light which prevents reaching complete black is clearly shown. Calculation of the efficiency on the complete control system shows a value to 40% for full modulation. Taking into account the fact that 50% of the light is absorbed by the slit system, the net light efficiency is approximately 20%. In other words, for a

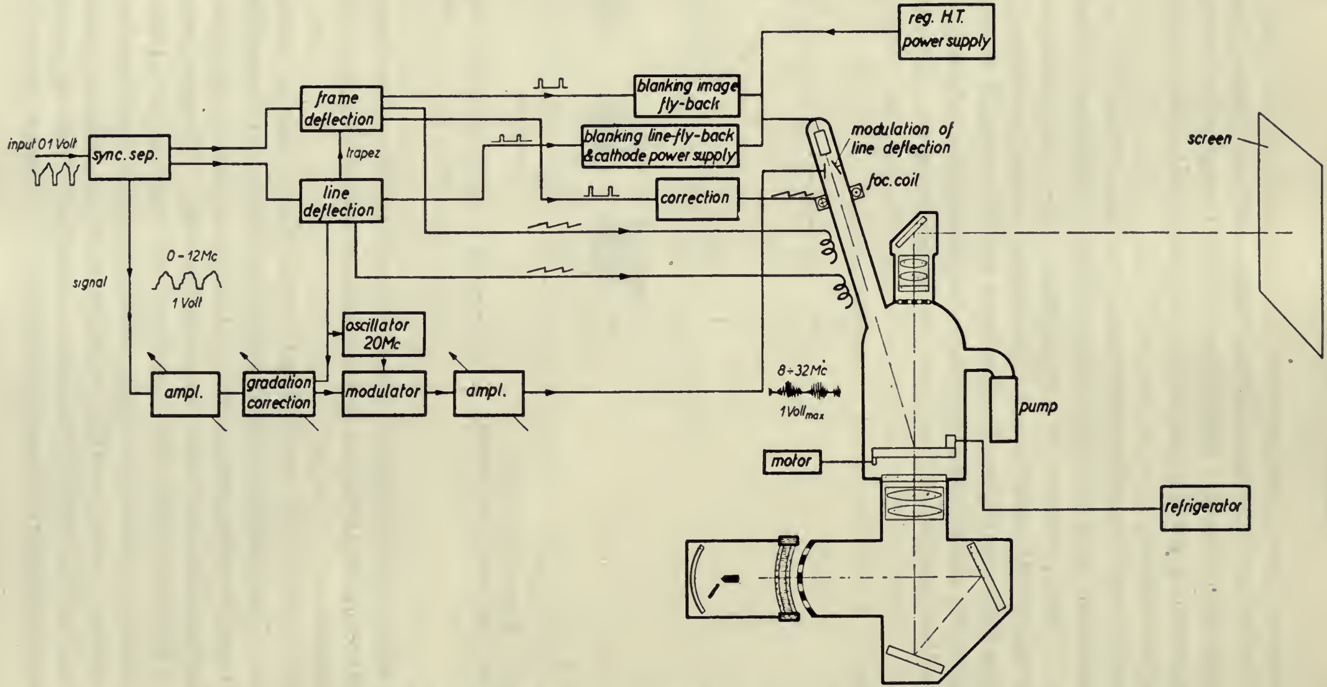

Fig. 6. Block diagram of the large screen projector installation.

light flux of 6,000 lumens on the screen, one would need an arc lamp of 30,000 lumens. For good light control the requirements of minimum stray light is not easily met. Many secondary causes may add to the ultimate amount of stray light, but the most important of all sources of remaining background light is reflection on glass surfaces. It is absolutely necessary to make all the glass surfaces within the Schlieren optics free from reflection. The laboratory equipment built at the Zurich Polytechnical Institute has met these requirements very well. Actually, one of the major qualities of the pictures demonstrated in Zurich is the excellent contrast which can be achieved combined with a smooth gradation curve. It seems to be rather superior to the pictures which can be produced with most cathode-ray tubes.

Figure 6 shows the block diagram of the large screen projector. The figure is self explanatory. The design and construction of the various electronic parts shown in the block diagram have not always been easy; but the problems they raise are of conventional nature and it does not seem necessary to present detailed comments concerning this part of the system. The preparation of a suitable eidophor liquid presents a much more difficult and original problem. The liquid has to meet very stringent specifications. Since it operates in high vacuum, its vapor pressure has to be very low, if possible appreciably lower than 10^{-5} millimeters. The conductivity, viscosity, dielectric constant and capillarity have to be inter-related by a specific relation which can be found from a theoretical study of the modulation conditions. The color of the eidophor must not have a disturbing effect. Finally, the eidophor has to withstand the bombardment of the cathode beam without being destroyed. After considerable experimenting, a suitable liquid has been found which seems to be reliable and which does not seem to be altered after long periods of operation. This is basically a mineral oil with suitable additions to bring the conductivity up to the desired value.

The arrangement as used thus far is shown in Fig. 7. The eidophor liquid is spread on a glass plate on which there is applied an electrode in the form of a transparent metallization. The glass plate moves very slowly (one turn in many minutes). After the liquid has been used for several picture frames, it is brought into contact with a cooled metal plate. After it leaves the cooling plate, it is smoothed out again by means of a straight edge or a rake into an optically perfect surface.

The movement of the eidophor is intended to permit cooling of the eidophor and to avoid disturbing border phenomena produced by

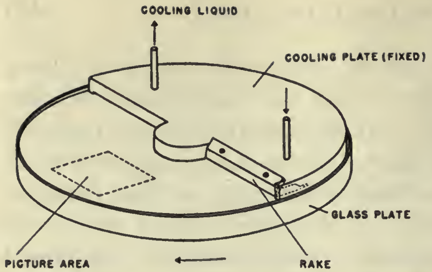

Fig. 7. Eidophor carrier with rake and cooling arrangement.

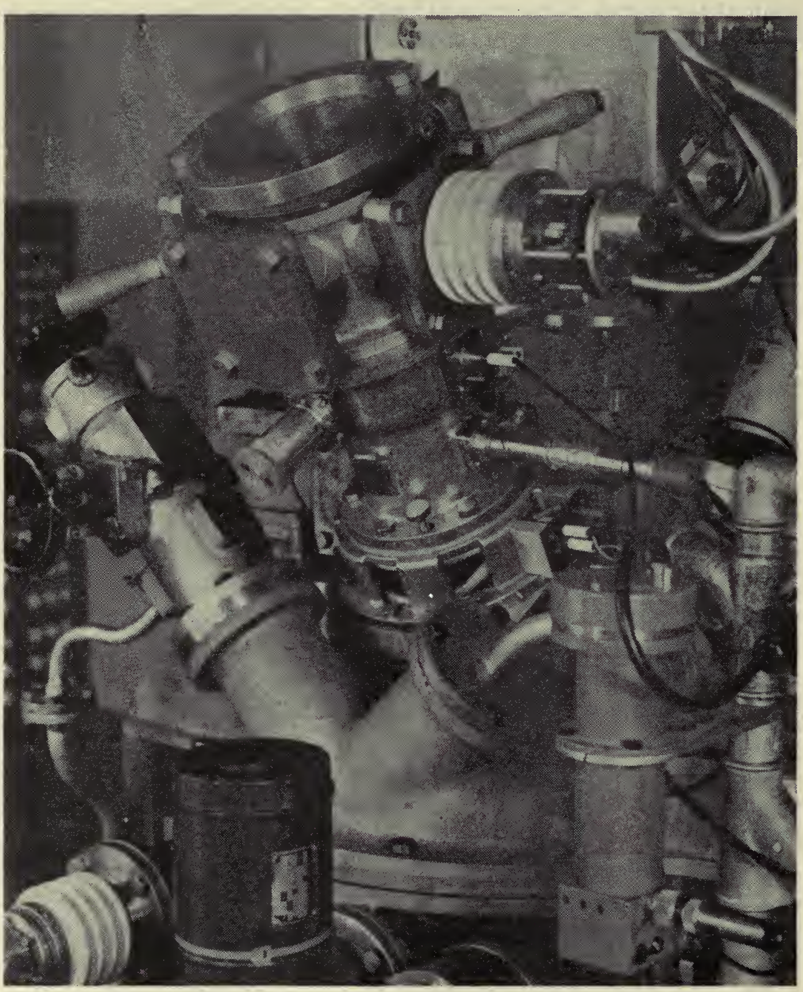

Fig. 8. Detail of the completed large screen projector: cathode-ray tube on top and center; eidophor plate holder below; holder for output slit system in back of cathode-ray tube.

electrostatic charges which would be accumulated on the eidophor if it were continuously submitted to the electron bombardment.

The various requirements briefly mentioned above for operation of the eidophor and the accuracy of the design for the optical system have led to a first experimental model which is quite complicated and is in no way intended for commercial applications.

Figures 8, 9 and 10 are pictures of some of the elements of the complete machine and show how complex and large a structure it is. The plate holder shown in Fig. 9 is approximately 6 ft in diameter. The whole machine occupies two floors, the arc lamp being at a floor below the projection room. The complexities of the present installations should not prejudice the possible future applications. Professor Baumann has worked out a project for a new model and has authorized me to present the expected over-all dimensions of this new machine, shown approximately in Fig. 11 as: height, 5 ft; length, 5½ ft; width, 2½ ft; and weight 1800 lb.

The great saving in size and volume as compared to the present system is due to a new conception of an optical system as it appears from Fig. 12. The light, instead of traversing the eidophor once as in the present system, will be reflected by the parabolic mirror and will return on the same slit system. Many advantages are expected from this new arrangement, such as continuous cooling by the parabolic mirror, very slow motion of the mirror (one revolution in one hour), inexpensive optical system, very high contrast ratio (1 to 300), and convenient aperture of the final light beam (1/7.4). With an arc of approximately 70,000 candles per square centimeter, Prof. Baumann expects to get a maximum light flux of approximately 7,000 lumens on the screen. Like the first laboratory model, the whole equipment will be evacuated continuously by means of a rotary pump.

From these very brief descriptions it can be seen that the eidophor-projection system, while still in the experimental stage, is progressing toward a more practical solution. The new project on which the experts of the Polytechnical Institute of Zurich are working is quite promising and would represent an equipment which in complexity and size is not very different from the latest projection systems using cathode-ray tubes. It should be noted that the Swiss system is intended for installation in the normal projection booth of the movie theater and from that point of view it has a considerable practical advantage over the cathode-ray tube systems using Schmidt optics.

To conclude, I would like to remind you once more that the remark-

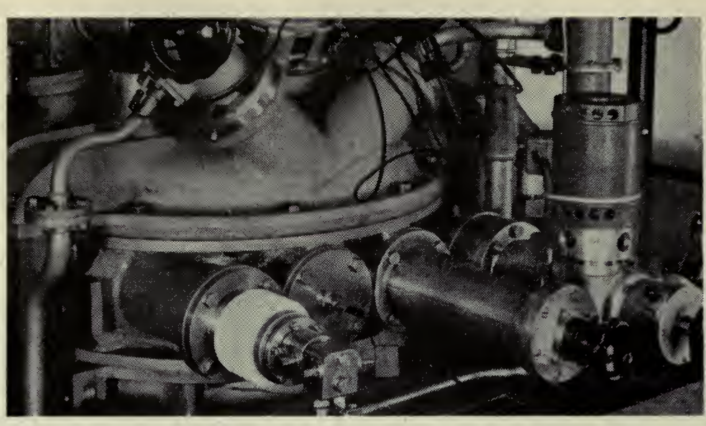

Fig. 9. Detail of completed large screen projector: eidophor plate holder at left; pumps' connection at right; cooling liquid connection at extreme left.

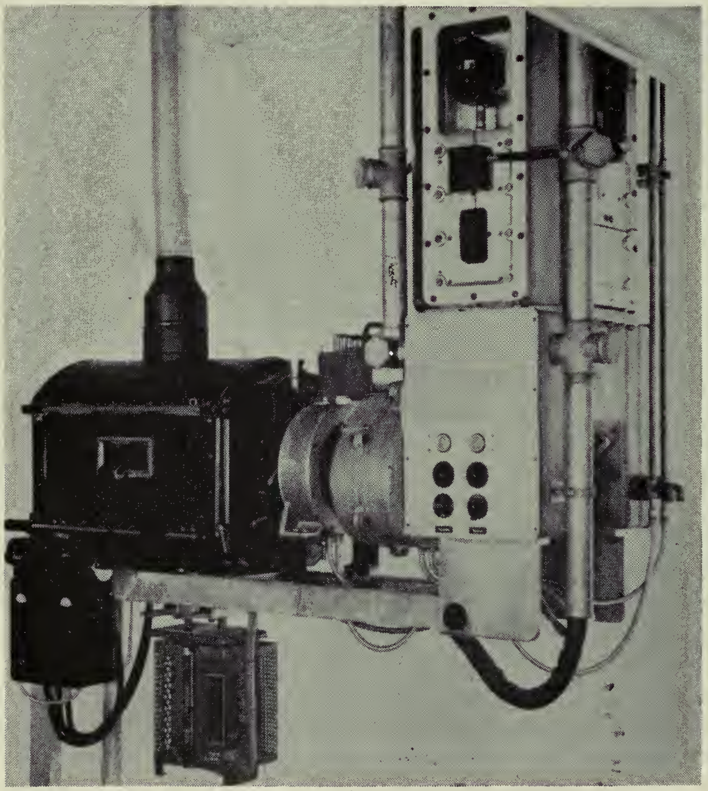

Fig. 10. Detail of completed large screen projector: arc lamp; optical system before reaching eidophor (eidophor holder is on floor above).

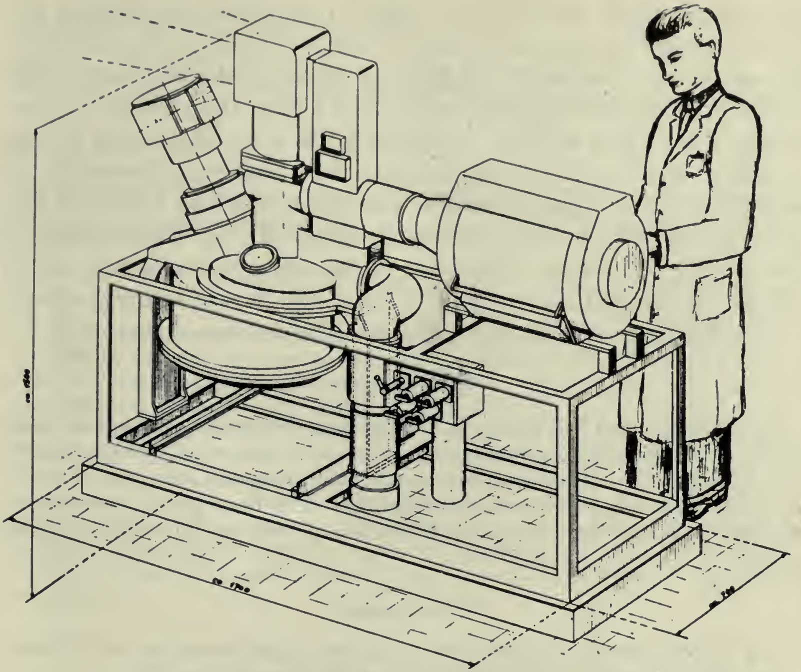

Fig. 11. Projected plant.

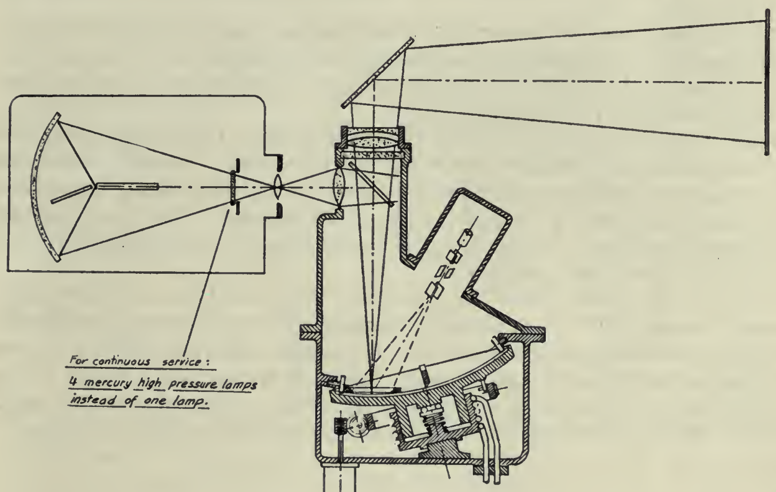

Fig. 12. Projected plant diagrammatic structure, with radar-purpose mercury high-pressure lamps.

able development which I have tried to summarize is being undertaken entirely at the Polytechnical Institute of Zurich by Professor Baumann, Dr. Thiemann and their colleagues. At the request of the SMPTE Theater Television Committee, I have tried to give a short description of this system. I do not know if it will ever be a commercial competitor for the cathode-ray tube projection system, but it would be very surprising if such a remarkable new tool would not find some useful applications. I want to thank Mr. D. E. Hyndman of the Theater Television Committee for the opportunity he gave me to talk at the SMPE Convention and I also wish to express my gratitude to Dr. Thiemann who supplied the material for this paper.

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(1) F. Fischer and H. Thiemann, "Theoretische Betrachtungen uber ein neues Verfahren der Fernsehgrossprojektion," *Schweizer Archiv*, vol. 7, January, February, November and December, 1941; vol. 8, May, June and July, 1942.

(2) H. Thiemann, "Fernsehgrossprojektion nach dem Eidophorverfahren," *Bulletin De L'Association Suisse des Electriciens*, p. 585, No. 17, August 20, 1949; Zurich.

Discussion

MR. W. W. LOZIER: Approximately what was the picture size on the eidophor?

DR. LABIN: Approximately twice the normal motion picture size.

MR. LOZIER: Can you give any lumen values of what you have obtained on, say, a white screen?

DR. LABIN: Yes, we have obtained 1500 lumens on a screen which was ten meters square. I am quoting from memory of the papers.

MR. LOZIER: Do you know approximately what speed projection lens was used, whether there are any limitations there?

DR. LABIN: No, I don't think there are limitations. They impose themselves to work with a normal angle of projection used in theaters. I mean they consider it as a must to install their machine in the normal projection rooms. It would be considered as a must, in view of the size of the machine. They have no other limitations that I see. I do not have the final efficiency in terms which would even indirectly answer your question.

MR. LOZIER: That is what I was thinking. You would have a focal length, I think, of roughly twice what we use in theaters now. If you have a picture twice as big to start with and speeds in those focal lengths might run to $f/3$ or $f/2$, will the rest of the system fill such a speed? Can it be designed to do that?

DR. LABIN: Oh yes, there is no limitation to that. If you question the actual optical efficiency of the system, it is certainly not as good as normal projection.

Standard Television Switching Equipment

By RUDY BRETZ

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Summary—There is a considerable difference in design among the standard switching systems put out by the three major television manufacturers. General engineering departments of the major networks and many of the independent stations have designed and built their own systems. All studio switching systems should permit the operator to fade to black, lap-dissolve and superimpose. Not all will permit more complicated effects such as cutting to a superimposure, or cutting away from a superimposure to a shot on another camera. Not all will permit the operator to preview a superimposure before he makes it. The following article lists the requirements of television switching systems from the operating point of view and describes the operation of the standard models which are in use in television stations today.

Switching System Design

Positioning of the Switching System

Most control rooms are laid out in a two-tier arrangement with video engineers and camera control units on the front and lower tier. The second level provides a table for the director and usually for an assistant as well. The location of the audio engineer varies between one level and the other, or he may be placed at the side of the control room, not in either tier. The bank of buttons and other controls, known as the switching system, is also found sometimes below and sometimes above. Figure 1 shows four different methods of control room layout. The technical director (T.D.) may sit at the same console as the video engineers (a), or he may sit beside the director (b, c, d). NBC (d) likes to place the video men and camera monitors off to the side and leave the T.D. and the director alone in front of the control room window. Only a master monitor and one preview

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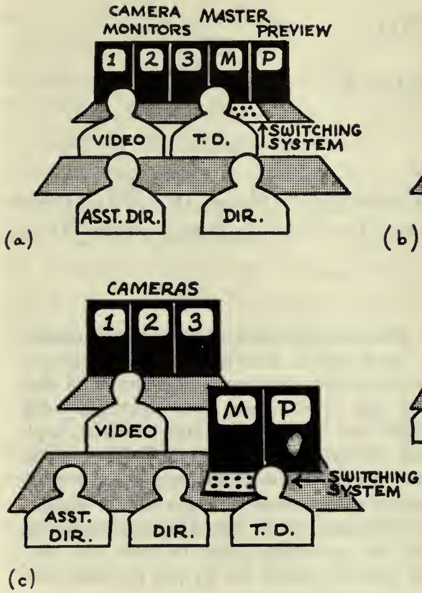


Fig. 1. Four methods of control room layout.

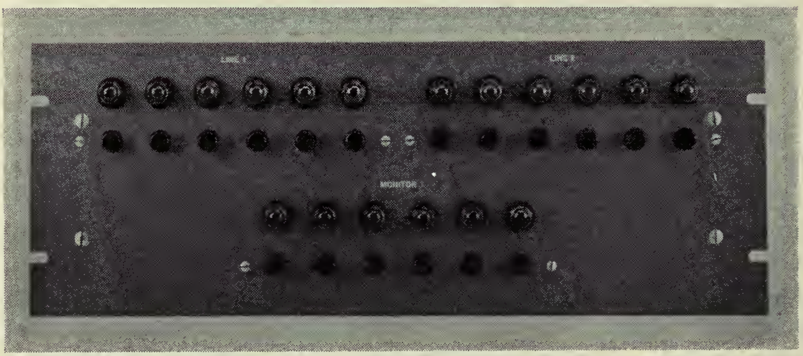


Fig. 2. RCA Switching Panel Type TS-1A.

monitor are used by the T.D. and the director under the NBC system.

The manufacturers of switching equipment usually build their switching systems into consoles, in some cases combined with a master monitor and in other cases with a preview monitor as well. The RCA studio switching system (Fig. 12), which is combined with a

master monitor in this way, can be removed from the monitor if desired. Stations sometimes mount the switch panel in the production table on the second tier, leaving the master monitor down below. Most of the specially built switching systems are installed in this manner.

In the remote truck that WBKB has designed and built (one of the best designed trucks in the industry), there are two sets of buttons: one below at the T.D.'s desk, and one on the upper desk for the producer. It is possible for the T.D. to punch a "remote control" button and throw the switching operation entirely to the director of the program, who then operates from his own set of buttons.

Incoming Picture Signals

A studio switching system must be designed to handle more incoming picture signals than merely those emanating from the cameras in the studio. Projection equipment is often used for titles or film portions of studio shows, and the film channels must also be controlled from the studio switching system. In small stations, the studio control room functions also as the film control room, sometimes actually containing the projection equipment in a back corner. In such cases, the film channel or channels normally feed through the studio switching system.

By-Passing the Studio Switching System

When a film or test pattern slide is on the air and feeding through the studio switching system, the studio cannot be used for camera rehearsal. Any switching would disturb the program on the air. For this reason, there is always some means provided for by-passing the studio switching system and feeding directly from film camera to transmitter. The same by-passing is provided for other incoming signals, such as network programs from AT&T (if the station is on the coaxial cable), or a picture from a remote pickup. A series of master switching buttons is installed for this by-passing purpose, in the circuits between the studio switching system and the transmitter. Sound, of course, must be handled identically, but audio is a parallel system and not the concern of this chapter. Figure 3 shows the master switching panel for by-passing the studio switching system. Buttons shown in black are on. The film camera is feeding through the by-pass circuit directly to the transmitter, while the switching system is feeding only the client's booth and monitors.

Preview Switching

It is always a great risk to put anything on the air without being able to watch it right up to the moment of the switch. Any picture which does not appear on a camera-control monitor in the control room must be previewed somewhere before being switched onto the air. Film channels which are monitored and controlled elsewhere will have to be previewed in this way. When remote pickups are to be integrated with studio presentations, they also must be previewed.

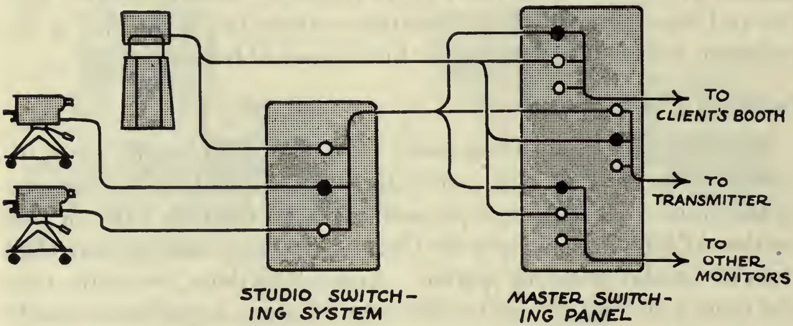


Fig. 3. Method of by-passing studio switching system.

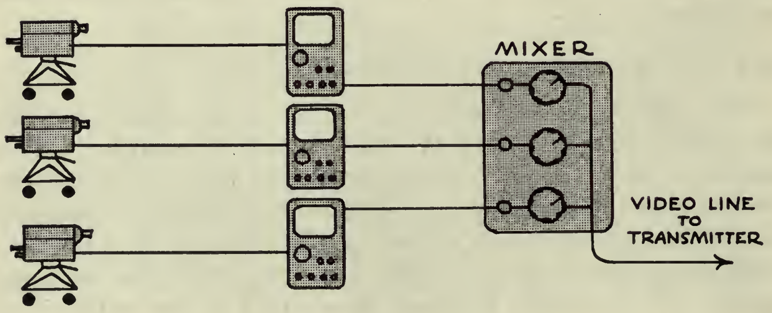


Fig. 4. Mixer type of switching system.

This is particularly true on occasions when live or film commercials from the studio must be inserted into ball games or other sports events. At these times, the ball game will sometimes be fed through the studio switching system on its way to the transmitter, so that the studio-originated portions can be cut in. Any good switching system must provide a method of selecting the channels that are to be seen on the preview monitor.

Some switching systems, which have a master monitor built into the same unit, make it possible to use the master monitor for previewing these incoming lines. This is a poor practice, however, since it sacrifices the master monitor during the time another channel is being previewed. It results in a type of previewing which amounts to only a quick glance at the next picture, and it certainly is not desirable for best programming results.

Dissolves

A switching system must also be designed to fade channels or cross-fade them so that dissolves, fades and superimposures can be accomplished. There are three common ways to design a switching system to do these things.

1. The Mixer Type. The first system provides each channel with a separate gain control, and runs them all together into a mixer, just as the outputs of many microphones are mixed in an audio console. This kind of switching system may have separate switches, as well as separate fading controls. The old Mt. Lee studio of KTSL had such a switching system, built according to the studio's own design. It had seven positions for fading, but no switches. Instantaneous cuts had to be approximated by very quick dissolves. The Dumont "mixer," which is a switching system of this general type, provides for only four channels, but has switches and a number of additional features and refinements (Fig. 4).

2. The Dual-Fading-Bus Type. The second type of switching system provides two basic master channels, which feed through two fader controls. They are usually termed "channel" or "fading bus" A and B, and all of the video channels which feed into the switching system can be punched up on either one (Fig. 5).

Only one of these two channels is used when straight switching is desired; the fader control for the channel being used is left open and the fader control for the other is closed. If you have been using Channel A, for example, and wish to make a dissolve, first punch up the camera you will dissolve to on Channel B, then simultaneously fade out Channel A and fade in Channel B. There will be a further discussion of this later in this chapter under "Specific Equipment." The RCA studio switching system is of this design, as well as the General Electric switching system which is built into a program console.

3. The Three-Bus Type. The third system has three master channels, two of which are for fading and dissolving, as just described, while the third is used for straight switching. The straight switching bus has an extra button marked "Effects," through which the combined output of the two fading buses will feed whenever dissolves or superimposures are desired. This has an advantage over the second

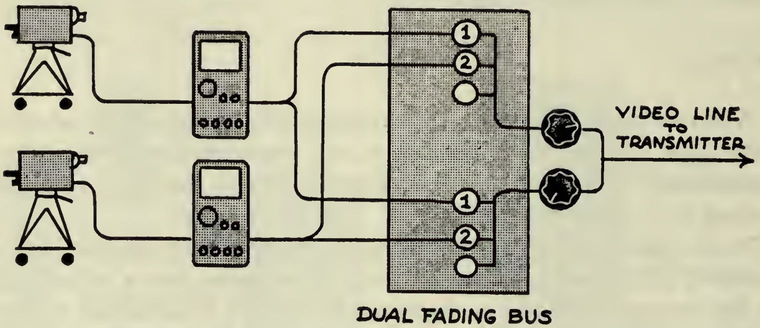


Fig. 5. Dual-fading-bus type of switching system design.

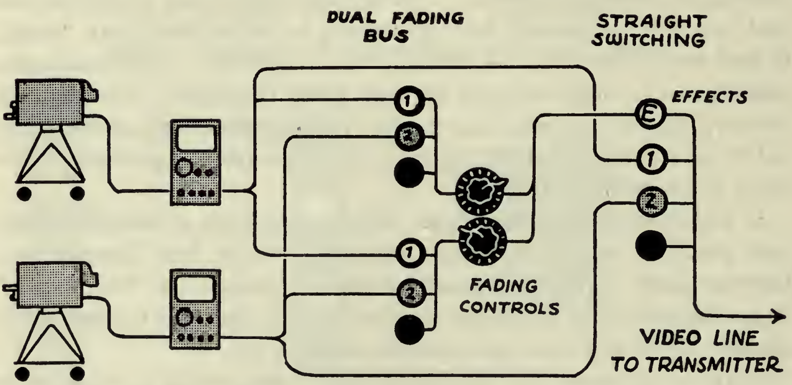


Fig. 6. Three-bus type of switching system design.

type of switching system in that it permits switching to a superimposure or switching away from a superimposure to a single camera (Fig. 6).

This type of switching system was developed by NBC and has been installed in all the NBC-owned stations. The RCA switching system, which is built into the Program Director's Console, is of this design. CBS has made some very useful additions to this equipment.

SPECIFIC EQUIPMENT; HOW TO OPERATE SWITCHING SYSTEMS

The RCA Field Switching System

The RCA Field Switching System, first on the market in 1946, is very frequently seen, not only as remote equipment, but in studio use as well. This equipment originally had no provision for making dissolves, and several ingenious devices have been developed to adapt it to this purpose. RCA now offers a special auxiliary unit which is equipped with dual fading buses similar to the RCA studio switching system (Fig. 7a).

The control face of this switching system is divided into three horizontal areas. At the top is a bank of 13 switches which control a very complicated and flexible intercommunication system, described in detail in the chapter on intercommunication. Beneath the cover in the middle portion is an intercom jack panel, containing six plug-in points for the engineers' and director's headphones.

The lower third only is concerned with switching of picture signals. There are two rows of buttons with associated tally lights to show which channel is on the air. The top row is for monitor switching and the bottom row controls the outgoing picture line. The monitor-switching feature, as explained above, makes it possible to use the master monitor as a preview monitor when working with limited equipment. The master monitor is, of course, a separate unit.

Six incoming signals are provided for in this switching system. Four of these are intended for camera channels and two (auxiliary 5 and 6) for incoming channels, usually from a remote source.

Monitor switching allows the master monitor to be used for several purposes in addition to its regular use as a master monitor on the outgoing picture line. Either of the incoming pictures lines, 5 or 6, can be previewed by punching the appropriate buttons. The engineer has occasional need for checking the picture at various points in the system—for instance, at the input and output of the relay transmitter—when this equipment is being used in field pickup; provision is made for these purposes also. In actual practice, on a remote pickup, monitor switching is used only in case of emergency. It would be extremely confusing to a director not to know if the picture being shown on the master monitor is on the air.

The knob above the monitor switching buttons is concerned with the two auxiliary lines 5 and 6. When a picture is coming in from a remote source, say another studio or a field pickup, the equipment in

Fig. 7a. Control panel of RCA Field Switching System, Type TS-30A.

that location probably includes its own synchronizing generator, and the incoming signal is a composite signal; that is, the synchronizing pulses are already combined with it. In the case of the camera channels, the signals coming in to the switching system are pure video, and the synchronizing pulses are added in the switching system just

before the program goes out to the transmitter. When the incoming signals on lines 5 and 6 are complete with synchronizing signals, the switch knob is set to EXT (external sync). If, instead, picture signals from additional cameras or film pickup chains are fed through the auxiliary lines, these are not composite signals and synchronizing signals must be added. For this the switch is set to INT (internal sync).

Dissolves with the RCA Field Switching System. The TS-30A switching system provides for straight switching only, since when it was designed in 1945 no one anticipated the need for dissolves or superimposures in the field, and studio use of this equipment was not contemplated.

A great many small stations have installed this field equipment in their studios, however, because of its low cost. Naturally, the requirements of studio production make dissolving, at least, a necessity. In the field an even greater use has been found for the superimposure than for the dissolve. During brief intermissions in a game, the director may want to show the sponsor's name or symbol on the screen as a visual complement to a short commercial, without at the same time giving the audience the feeling of losing contact with the field, where action may begin again at any moment. In such cases, a superimposure is very valuable. A very striking effect is often achieved by superimposing a close-up of a beer bottle, for instance, on the baseball field in such a way that it looks like a gigantic bottle actually resting on the field. Perspective must match to achieve this.

It is possible, with a little co-ordination between video engineer and technical director, to use the equipment as it now stands to effect a very credible dissolve. It has been found that two of the video switching buttons can be depressed at the same time, putting two signals on the air simultaneously. The result of this is, of course, a sudden superimposure when the second channel is added, an effect which is very rarely of any value. But if the second channel is added in a faded-down condition, and then the gain brought up after it is on the line, a slow appearance of the superimposed shot is effected. If the first picture is faded down at the same time that the second picture is brought up, a dissolve is the result. The gain controls are not associated with the switching system, but are found on the camera control units. Consequently, a very exact co-ordination is necessary between technical director and video engineer to make this result

possible. I have seen it done by one man in the studio at KTSP-TV, where only one engineer was available for all the video functions (Fig. 7b).

The routine, with the proper director's cues, is as follows:

1. "Fade down Two." (Assuming that Camera One is on the air, the desired shot is framed up on Two and the cameraman is told to hold it, while the instruction to fade down is given.)

2. "Add Two." (Camera Two is punched up on the switching system, but Button One must be held down, so that it won't automatically switch off since all buttons in each row are mechanically interlocked. Since Two is now faded down, there is no visual effect except a slight tonal change due to the added circuit.)

3. "Dissolve." (The dissolve can now be effected by simultaneously fading down the gain on One and fading up the gain on Two.

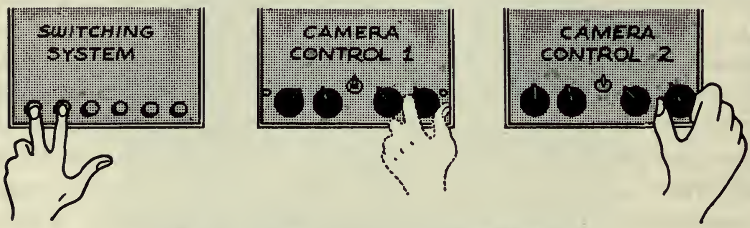


Fig. 7b. Simple method of making dissolves with RCA Field Switching System.

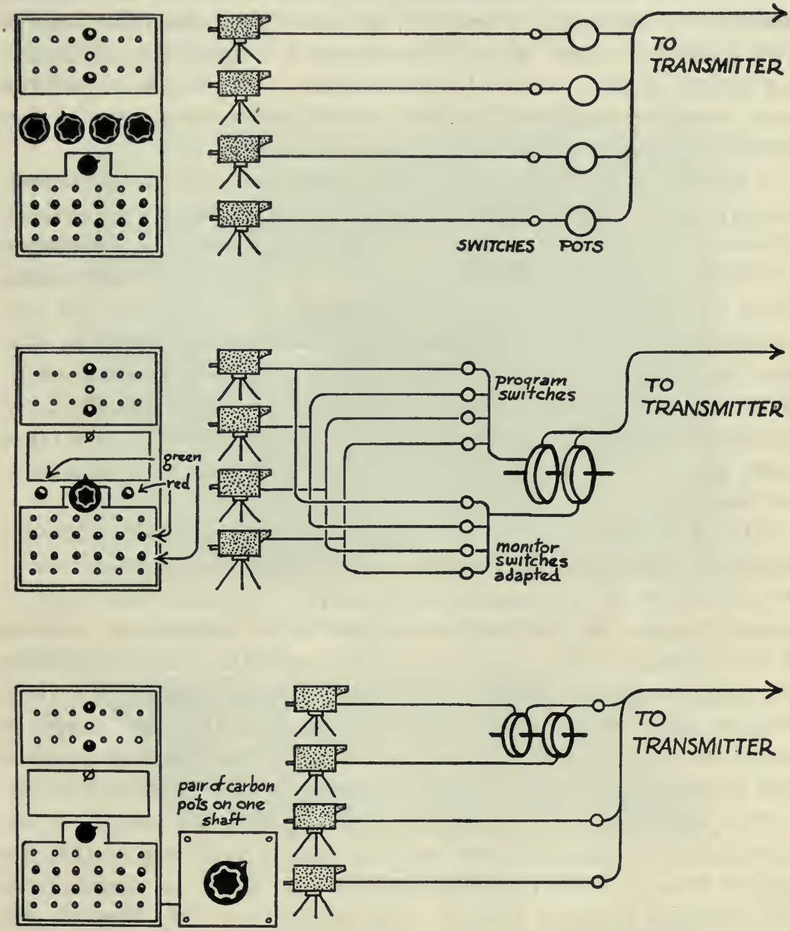
To be properly co-ordinated, this must be done by one person, and of course, he must watch the master monitor during the process. It may be found, for instance, that it is best to fade in Two about halfway before starting to take One out, or a dark period will be noticeable in the middle of the dissolve.)

4. "Drop One." (It is now necessary to take Camera One off the line, before any cuts are made, unless a dissolve back to One is expected. To take out One, Button Two must be held down while one of the other buttons is depressed just half way, far enough to trip the automatic release which snaps out Button One.

5. "Fade up One." (When the dissolve was effected, Camera One was faded down to black; before it can be used again, the gain must be turned up. This final step is frequently forgotten in learning this method of making dissolves.)

A strange effect is noticeable on the camera monitors when two switching system buttons are held down. The picture from each

camera feeds back through the line from the other camera and appears on that camera's monitor as well. This is not noticeable if the above routine is carried out properly, since one camera is always faded down while two buttons are depressed.



Figs. 8, 9, and 10. Adaptations of RCA Field Switching System to permit dissolves.

Special Adaptations of the Field Switching System. The method of effecting dissolves just described requires more co-ordination between various operators than most television stations like to rely on.

A self-contained switching and dissolving unit is much simpler to operate.

One method of adapting the field switching system for making dissolves was devised by WENR-TV in Chicago (Fig. 8). That station mounted separate potentiometers (fading dials) for each of four channels in the space where the intercom plug board is located. This method changed the switching system to a mixer type of dissolving system, similar to the Dumont mixer. The intercom facilities were, of course, sacrificed, but that was not serious, since most studios prefer to use their own separate intercom systems.

A second method is to convert the equipment into a dual-fading-bus type of switching system; one bus is the regular set of program selector switches, the second bus is the set of monitor selector switches. A separate potentiometer can be connected to each of these fading buses and mounted on the face of the switching system, or two potentiometers can be mounted face to face on one shaft, so that they work in opposite directions and only one dial is necessary. With two potentiometers on a single shaft, however, all that can be accomplished is a dissolve, since one channel fades in as the other fades out. With separate control, fade-outs and superimposures can also be effected (Fig. 9).

A third method is to feed only two channels into a separate dissolve control. This method may make use of a pair of potentiometers on the same shaft, or two separate dials, mounted in an auxiliary box. A certain number of studios are equipped with complicated versions of this "dissolve box," some containing separate dual-fading buses and camera-selector switches. The most common dissolve box, however, is rigged up to handle only two channels. It is very simple to install and at least 80% of the dissolving or superimposing needs of field programs can be met if only two channels are available (Fig. 10).

RCA now offers an "Auxiliary Field Switching Control" which operates in the same manner as their studio switching system described below. Since this is a separate box, it can be remote from the switching system if desired. Six channels may feed through this switching control which then feeds into the "Aux 5" button on the switching system. Five inputs are still usable on the switching system, in addition to the six that the auxiliary unit provides. A total of eleven local signals may be handled (six of which can be faded) or any combination of local and incoming remote signals may be used up to a maximum of seven remote and four local. This unit greatly expands the usefulness of the field switching system.

The RCA Studio Switching System

This equipment is often seen in both large and small studios. It is a dual-fading-bus type of switching system and is built into a unit with the master monitor. It is possible to remove the switching system from the monitor, however, and this has been done in some studios to allow either the T.D. or the producer to push buttons from the production desk.

Fig. 11. Auxiliary field switching control.

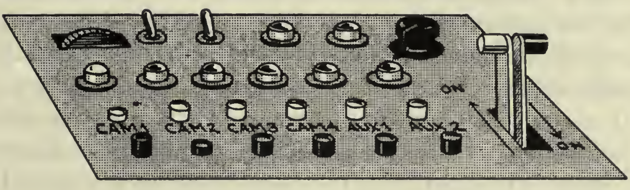


Fig. 12. RCA Studio Switching System.

Basically, this switching system is built around two rows of buttons, each feeding a fading bus. The two fading buses are controlled by levers which can either work separately to fade out one bus and fade in the other, or, as is more often the case, the levers can be clipped together to operate simultaneously for lap-dissolves.

In Fig. 12, the two lower rows of buttons are connected to the two

fading buses. The white row may be faded by the white handle, the black row by the black handle. Above the two rows of switches is a row of tally lights that show which channel is on the air. The tally light does not indicate which fading bus is operating; the position of the fading handles shows this.

Straight switching between cameras can be done with either bank of push buttons, providing the fading control for that particular bank is open. The signal from Camera One, in other words, is carried to *both* Button One on the white row of buttons and to Button One on the black row. When White Button One is punched, the signal goes onto the white bus and through the white fader control, if that control is open. If a dissolve is desired to, say, Camera Two, Button Two must be preset on the black row (since the black fading control is closed, nothing happens to the program line). When the moment for the dissolve comes, the white bus is faded out (with White Button One depressed) and the black bus is faded in (with Black Button Two in the ON position). The two fading dials work in opposite directions; that is, the ON position for the white handle is at the top, and the ON position for the black handle is at the bottom. Thus at the beginning of the dissolve, both levers will be at the top, and so it is possible to work them with one hand and simultaneously fade one picture out and fade the other in (there is a spring clip with which the levers can be fastened together).

Superimposures. The halfway condition in a dissolve is a superimposure, and the handles may be left in the midway position if desired. Each camera is then at half brilliance. This does not always make the best superimposure, however. Sometimes it may be necessary to superimpose a ghost onto a scene without making any noticeable change in the scene itself. The second camera, with the image of the ghost, must be added to the first, without lowering the level of the first signal. In this case the two handles are separated and the second one is brought up to the desired brilliance without lowering the first. Some operators like to keep their fading handles separated at all times, feeling that they thus have better control.

Cutting to or from a Superimposure. The manufacturer of the RCA switching system says nothing about achieving this effect. It is not supposed to be possible, in a switching system composed of two fading buses, to tie up both in a superimposure and then switch to another shot. There is nothing left to switch to; everything is in use. If another camera were punched up on either of the fading buses, the

new picture would simply take the place of one of the other camera signals within the superimposure. One of the cameras must be lost from the superimposure before straight switching can be done. The same is true in getting into the superimposure. A straight shot must be taken first and the superimposed picture added; the two cannot appear at once. Technical directors with skill and ingenuity have discovered ways, however, to operate this equipment and effect a cut to a superimposure or away from a superimposure to a single shot.

A practical problem like this sometimes arises: A girl enters a room, sees a ghost, and speaks to it. If the ghost were to materialize slowly before the girl's eyes, the problem would be easy. But the ghost must be *in* the room as soon as we see it. We must then cut from the room-and-ghost shot to a shot of the girl as she speaks.

One method of doing this is as follows: Camera One takes the girl as she enters the door, Camera Two, the room, and Camera Three, the ghost (an actor in another set, brightly lighted against a black background). Camera One is on the air. If One is punched up on, say, the top row of buttons, punch it up also on the bottom row and set the handles halfway. Half of the Camera One signal is then coming through one fading bus, and half through the other. Now place one finger on Button Two in the top row and a second finger on Button Three in the bottom row, and press them both at once. Of course, there has been no way of previewing the superimposure. You are cutting blind, so to speak, and, unless you rely heavily on the cameramen to mark their finders during rehearsal and repeat the exact framing they had then, you will not be quite sure whether the ghost will seem to be standing next to or inside the furniture, with his feet on the floor, or floating several inches above it. To cut away from this superimposure back to Camera One again as the girl speaks, simply press both Camera One buttons at once.

A second method of doing this is a little more difficult. With Camera One on the air as before, punched up on the top (white) row of buttons, a cut to a superimposure of Two and Three is desired. In this case, preset Black Button Two and hold a finger ready on Button Three in the white row. Both fading handles will be in the top position as shown in the illustration. At the same instant, press Button Three in the top row and bring the fading handles down halfway. To cut back again to Camera One by this method, simultaneously punch Button One in the top row and bring the fading handles to the top.

RCA Program Director's Console

This switching system is similar to the one just described except that it is built into a console containing three monitors, intercom controls, talk-back microphones and working table space for three. The table is for the T.D., the program director, and his assistant (Fig. 13).

An unusual feature of the monitors is that they are mounted vertically in the cabinet below the table and are viewed through a mirror.

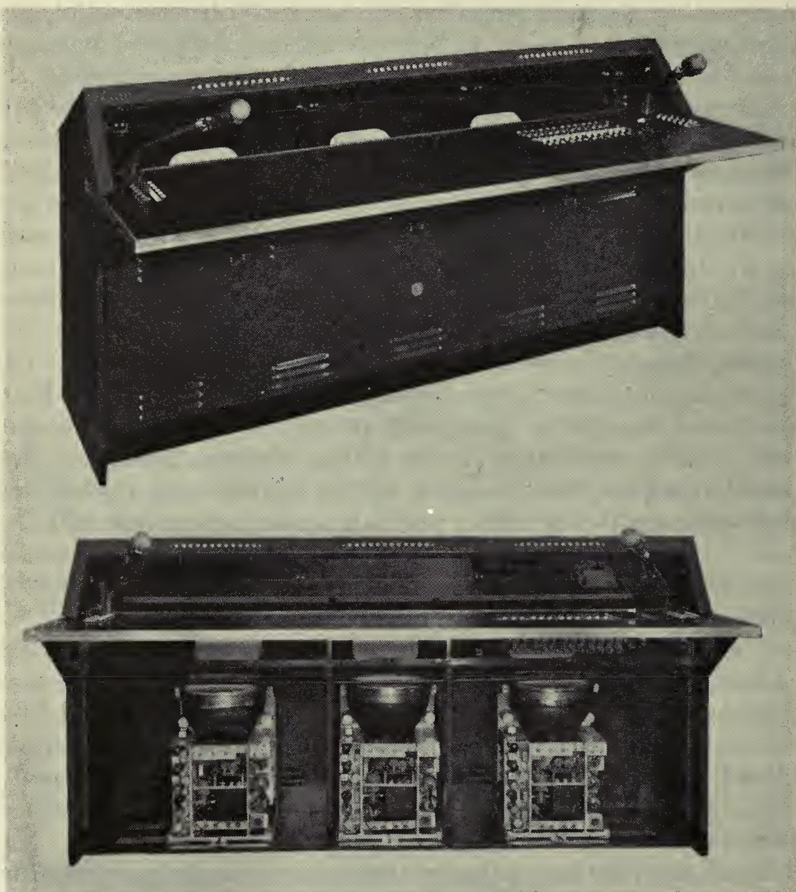


Fig. 13. RCA Program Director's Console.

This permits the top of the console to be very low, making it possible for the director and the T.D. to see the camera control monitors and into the studio from a seated position.

This equipment is used in a number of ways. Some studios mount the maximum of five monitors in the console, so that the director may have the three camera monitors in front of him, with a master monitor and a preview screen as well.

The manufacturer intended the three screens to be used for: (1) preview; (2) studio switching master monitor; and (3) on-the-air master monitor. The difference between a studio switching master monitor and an on-the-air master monitor is a little obscure to the average production man. The engineer will use the studio switching monitor to show the results of operating the studio switching system, and the on-the-air monitor as a check on the condition of the picture farther on in the circuit and as a cue monitor.

In actual practice, the two side screens are most often used as preview screens, but the exact use of the console is a matter of personal preference. Some directors at CBS use it only in connection with the regular camera control monitors, which they can watch down beyond as in Fig. 1 (c). They use the left preview monitor only for film, the right only for still pictures. Even with three studio cameras, I have found it quite satisfactory to do the entire show without referring at all to the camera control monitors. The middle screen is a studio switching monitor. Camera One is always previewed on the left; Camera Three always on the right. When One is on the air, Two is found on the left monitor; when Three is on the air, Two is found over on the right. This is really not as confusing as it may at first seem, since each monitor has a series of numbered tally lights above it, and it requires but a quick glance to read what picture is displayed on each monitor. This previewing of camera channels is established as an automatic procedure to be followed by the T.D. without orders from the director. Channels other than these three camera channels can be previewed on either monitor at the director's request.

Switching System. Switching allows for a maximum of 12 different inputs in this console. Small stations will not utilize all these positions, but in a large network studio all may be needed. CBS, for instance, has five film channels in the projection room, and also a monoscope channel with test pattern. Any of these might be needed for a studio show, so that all must feed into each studio switching

system. A possible maximum of four studio cameras (five have been used on complicated shows) brings the total number of channels to ten. One channel must be used for the incoming cue line, which is necessary in a network studio and shows the on-the-air network program at all times. It is previewed by the studio control room just before going on the air so that in case of an error in timing, the show can wait until the line is clear. All of this leaves only one channel for a spare (Fig. 14).

The dual-fading-bus method of dissolving is used. One bank of buttons is white, and is controlled by a white fading handle; the other bank is black, with a black handle. The two fading controls work opposite to each other so that when they are moved simultaneously, one bus is faded out, the other in, and a dissolve is effected. This is almost identical with the RCA studio switching system. Two banks of push buttons at the top of the panel control the two preview monitors.

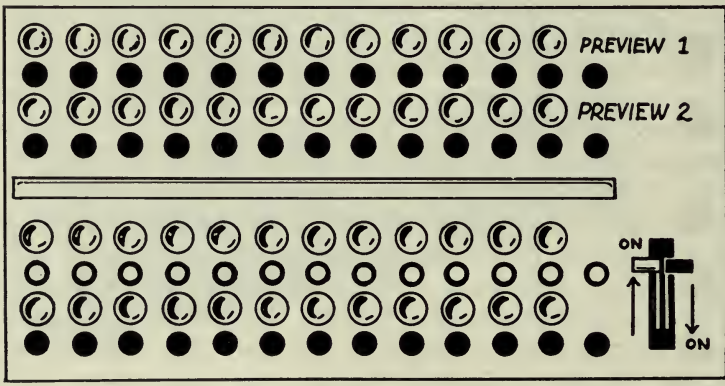


Fig. 14. Push-button panel used in RCA Program Director's Console.

CBS Adaptations from the RCA TC5A Switching System. Figure 15 shows how CBS has simplified this switching panel, and added another row of buttons. Instead of having a row of tally lights above every row of buttons, they have used a plastic button which is itself a light, and lights up as soon as it is punched; hence the simplification. The added feature is a row of straight switching buttons not connected with the fading buses, and not controlled by either fading handle. Figure 6 shows the relationship of these buttons.

The advantage of this is that one can cut to or from a superimposed effect. The last button (the 13th) on the row of straight switching buttons is labeled E, for "Effects." When that button is punched, the output of the fading buses goes out the program line. Thus it is possible to preset this entire effects system and preview the combined picture, and for this purpose an effects button is included in each row of preview buttons. To cut away from a superimposure, the next take is punched up on the straight switching bus, and the effect buses are dropped.

The only disadvantage in this type of switching system is that the director must give the T.D. sufficient warning before calling for a dissolve. If the cuts are being made on the straight switching bus,

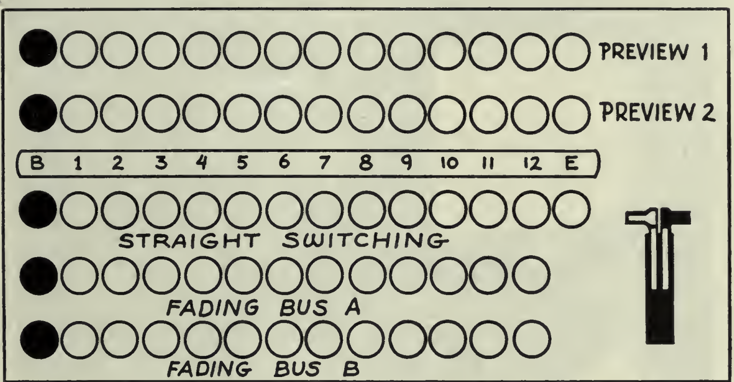


Fig. 15. CBS adaptation from RCA push-button panel shown in Fig. 14.

for instance, the T.D. has to bring the fading buses into operation before he can make a dissolve. To do this, he presets the same channel that is on the air on one of the fading buses and punches the E button in his top line. No effect will be seen and he is then ready to preset the other fading bus for the channel he is to dissolve to, and to make the dissolve. This does make dissolving a little more difficult, but it may well be a good thing, in the light of the great amount of meaningless, unnecessary and disturbing dissolves used in television today. Dissolves have been much too easy to do. A switching system which sacrifices some of the freedom in dissolving for added flexibility in other directions is, it seems, built to a good design.

An extra button has been added by CBS at the far left of each row

This is the black button (no signal). It is easier to make a fade-out by dissolving to black rather than by fading out one channel. The two fading handles are thus kept working together, which eliminates certain possibilities for error.

The Dumont Mixer

Dumont manufactures only field equipment, but it is frequently

Fig. 16. Dumont Mixer.

used in the studio. The field switching system particularly is well adapted to studio purposes. It is a mixer type of switching system, with separate fading dials for each channel. The manufacturer labels it "Mixer-Amplifier and Monitor," in recognition of the other functions incorporated into the same suitcase unit (Fig. 16).

Starting at the bottom of the mixer control panel, there is, first, a series of four tally lights for the four channels this equipment can handle. In the center of this row is an input socket for plugging in the T.D.'s earphones and talk-back circuit. Just above are the four fading dials, and above each of these is a push button switch. These four switches are mechanically interlocked so that if all faders are left open, straight switching can be done.

An unusual feature of this switching system is an automatic fade and dissolve, which can be actuated by these same buttons. Above the fourth push button is a dial marked "Auto Fade Rate." If this dial is set at "Instantaneous," pushing the channel buttons results in straight switching.

If the automatic fade dial is set on any of the other three positions (slow, medium or fast), a lap-dissolve or a fade-out–fade-in will be made. A small toggle switch to the left of this dial selects either the lap or the fade effect. The only manual control necessary is punching the button for the new channel; the dissolve or fade-out–fade-in then proceeds automatically at the selected speed. A fast lap is completed in 1½ sec; medium speed is 3 sec; and a slow dissolve takes 5 sec. The fade-out–fade-in proceeds at about the same speed as the dissolve.

Manual Operation. Since the automatic dissolve cannot be halted at a halfway point for a superimposure effect, another method of operation has been provided. In the middle of the row of camera switching buttons, divided from them by a white line, is a button marked "Manual Mixing." Punching this button throws all the other buttons into the ON position. Control is then exercised only by means of the fading dials.

During automatic switching all the faders must be open, but the switching buttons are interlocked, and only one channel at a time is switched into the mixer. When the manual button is punched, however, all the channels are switched into the mixer and will all go out at once as one big superimposure, unless their fading dials are first turned to the OFF position.

The transition from automatic to manual operation is usually made in this fashion: All the faders are turned down except the one controlling the channel which is on the air. The manual mixing button is then punched. There is no effect on the program picture, since all that the manual button has done is to turn on the other three switches. It is now possible to fade, lap or superimpose to any extent and at any speed, since everything is under manual control. If at any time a cut is desired, automatic cutting must be restored by punching the switching button of the channel that is on the air. No effect is seen, but all the other switches are then turned off. However, the faders also are off and must first be turned up before a switch between channels can be achieved.

Here is the routine again, applied to a simple example: Starting with Camera One, on the close-up of an actor, it is desired to cut to Two, on a long shot of the room, then superimpose a ghost with Camera Three, lose the superimposure and cut again to One.

Director's Cue	*Technical Director's Action*
1. "Take Two."	Checks to see that the automatic fader is set at INST. Punches Button Two.
2. "Ready to superimpose."	Turns down all dials except No. Two. Punches manual button.
3. "Superimpose Three."	Turns up No. Three fader.
4. "Lose Three."	Fades down No. Three fader.
5. "Ready to take One."	Punches up No. Two button. Turns up all faders.
6. "Take One."	Punches No. One button.

The method of operating this equipment usually is as follows: The right hand is kept on the automatic fader, ready to turn it to INST if the director calls for a take, or back to one of the other settings, according to the director's "ready" cue. The left hand is used for punching buttons and working dials on the first two channels. The right hand generally handles the third and fourth channels. If the director is not careful to give "ready" cues, however, he may call "Take" and get a dissolve (a very frequent phenomenon where this equipment is used). In general, it may be said that the automatic

dissolve feature increases the ease with which dissolves and fades can be made and leads to an over-use of these effects.

Cutting to or from a Superimposure. While the direct cut into or out of a superimposure was not intended as part of the function of the Dumont mixer, it is possible to achieve this effect by one of two methods.

The simpler method is to punch two buttons simultaneously. The T.D. must mark the position of each fading dial during rehearsal, and set them thus before the switch so that the balance between them will be correct. It is often found desirable when two channels are punched up at the same time, to leave the fading dials full open and regulate the balance between the two pictures by riding the pedestal controls on the camera control units. This requires either very close co-ordination between the T.D. and the video engineer, or close proximity of mixer and camera control units so that the T.D. can operate both. Cutting from a superimposure to another camera is very simple when using this method; punching up the new camera will automatically release the previous two.

A second method makes use of the manual button (which throws all switches into ON position at once). The T.D. opens the two fading dials that control the cameras which are to be superimposed and then punches the manual button. The cameras will go on the line simultaneously. Automatic switching is no longer in effect, however, and the first switch will not automatically snap off. Unless the first camera is quickly faded down when the switch is made, there will be three picture signals on the air.

To cut from the two superimposed cameras back to the single shot again, the T.D. simultaneously punches the button that controls this camera and turns up its dial. Punching the camera button throws the system into automatic switching and both the superimposed cameras are dropped from the line as the new camera is switched in. Since the fading dial for this camera had been closed before, it must now be quickly opened so that the signal can feed through.

To Delay a Fade-In. Sometimes a program will require a longer fade-out–fade-in than the automatic slow rate of 5 sec. In this case, the T.D. may punch the fade-out and quickly turn down the dial of the new channel so that the automatic fade-in will have no result. Then, when ready, he will fade in that channel manually by turning up the dial. Another way to do this is to make an automatic fade to black. Since the automatic fade effect always includes a fade-in

after the fade-out, if the picture is to stay black, the new channel must be a dead channel. The T.D. will turn down the fading dial on a channel which is not in use, set the auto-fade dial and switch, and punch the button for that dead channel. The live channel will fade out, the dead channel will "fade in" and the screen will remain black. Then, when he is ready to fade in the next picture, he will punch the appropriate button. The mechanism then makes a second automatic fade; the dead channel automatically "fades out" and the new picture fades in.

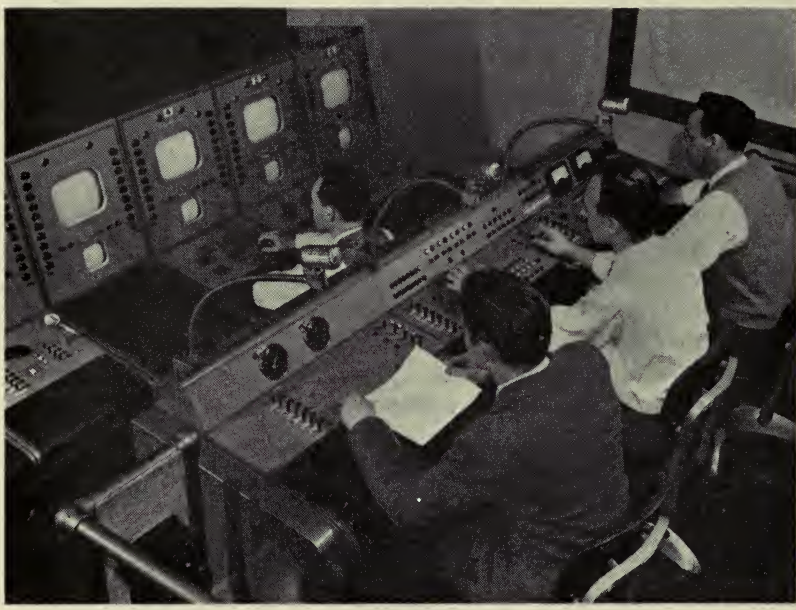


Fig. 17. General Electric Program Console.

Dissolving to a Superimposure. This is an effect which cannot very easily be accomplished on any standard equipment except the Dumont mixer. At the mid-point of this effect three cameras must be on the air at once. When the system is set for manual mixing, it is possible to fade down a dial with one hand, and fade up two more simultaneously with the other. This can be done, however, only if the two dials which are to be opened simultaneously are next to each other on the board. Technical directors with three hands are difficult to find.

General Electric Program Console

The switching system manufactured by General Electric is built into a console which seats three, the director, the T.D. and the audio engineer. Figure 17 shows this console in operation at WGN-TV in Chicago. General Electric has just placed on the market a new model which is part of its new line of television equipment. As far as its operation is concerned, however, it is reported not to differ greatly in any basic way from the console and switching system described herein.

From the standpoint of production, this is a beautifully conceived piece of equipment. Everything has been thought of and built in, even to telephone handsets at each position and recessed ash trays. All that need be added is a script and the inevitable container of coffee.

Monitors are not included in this console. It is intended for use with the General Electric Camera Control Desk, which includes large monitors, relatively high, so that it is not difficult for the director to watch them over the video operators' heads. The console can be used in the dark (a desirable condition where monitors are not hooded to keep off stray light). Every control label is printed in fluorescent paint, which glows brightly when the console is flooded with ultraviolet (black) light. For the illumination of scripts, a small white light is built into the bottom of each gooseneck microphone mount, which is adjustable to any angle.

The director's position on the left is equipped with a clock and built-in stop watch, plus a variety of intercommunication switches which can be hooked up to whatever combinations of circuits are desired. A disadvantage of this console is the lack of desk space for an assistant director. The assistant must work at an adjoining table or pull up a chair to the side and work without desk space.

The audio operator's console at the right is equipped with a five-position mixer (five fading dials), with two outputs. Operating experience has shown that five positions are too few in television, especially in a large studio. Each source of sound requires a separate potentiometer in general practice; and although there are ways of circumventing this, they are not very satisfactory. A further discussion of this point is to be found in the chapter on audio equipment.

The switching system in the center of the program console is of primary interest at this point (Fig. 18). It is a dual-fading-bus type

with the push buttons arranged in two banks, one for the left hand to operate, one for the right. Six inputs are provided. All of these may be used by cameras, or some may bring in film or remote signals. The method of operation is similar to that of the RCA studio switching system. Straight switching is accomplished by punching buttons in whichever fading bus happens to be in use. Two fading handles control the two fading buses. These handles are mechanically interlocked so that it is possible to make a dissolve by operating only one handle, the handle controlling the bus which is to be faded in. When this handle is faded in, the other automatically fades out. The interconnection does not function, however, when the handle of the fading bus that is on the air is operated. As this bus is faded out, the other will not automatically fade in, which makes a fade-out to

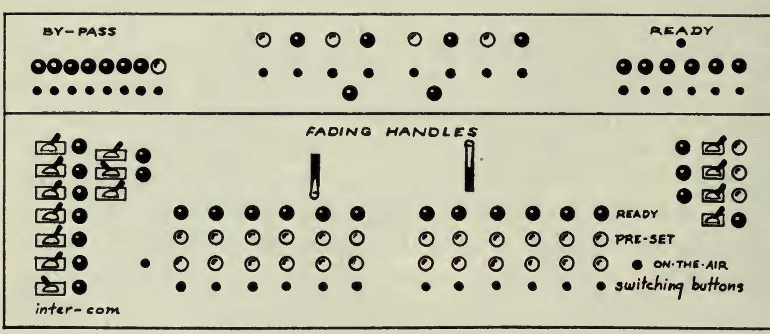


Fig. 18. General Electric Program Console switching system.

black possible. A superimposure can be made by stopping the handles halfway. Two channels cannot be superimposed at full strength, however, since bringing up the second handle automatically brings down the first one. This limitation makes the mechanical interlock feature a disadvantage in making superimposures.

Above each push button is a series of three tally lights, the top one green and the other two white. The bottom white one lights when the channel is on the air, and shows which channel is on and which fading bus is in use. The middle row of white lights is marked "Available" and indicates the channel that has been preset. These lights work on the fading bus which is not in use but is preset for dissolves. The green lights on the top row are preview or "ready" indicators. A light in this row shows that the T.D. has punched the proper one of a series of ready buttons which are placed on the top of

the console on the extreme right. When one of these ready buttons is pushed, a green ready light goes on in the camera and on the camera control unit and, at the same time, the green tally light, which was just described, goes on in the switching system. The two top lights, then, should be on before a dissolve is made, after which the bottom light is then added. Verbal ready cues are very helpful, but this ready-light system seems to be an unnecessary complication and I have not seen it utilized very often in actual practice.

Cutting to or from a Superimposure. There are two ways to do this on the General Electric switching system. The first method makes use of the built-in by-pass control. A special set of buttons (top row, far left) makes it possible to select any particular incoming signal and circuit it around the switching system. This is used, for instance, when a film is on the air (which would normally feed through the switching system), and a studio show must be rehearsed at the same time. It eliminates the extra switching panel which is used for this purpose with RCA equipment. This bank of by-pass buttons may be used for straight switching if desired.

Buttons on this bank control incoming program lines such as film channels and network line, and one button controls the output of the switching system. If the individual studio cameras are also fed through by-pass buttons, a camera may feed its signal to the transmitter without passing through either of the fading buses. The operator is then free to punch up two cameras on the two fading buses, set a superimposure, and cut to it by punching the switching system button on the by-pass bank. This button serves the same purpose as the E (Effects) button on the CBS modification of RCA's director's Console. The operator of the General Electric switching system may also preview this superimposure if he has a studio switching monitor. Such a monitor shows only the output of the switching system, and is not a master monitor since it will not necessarily show the picture on the program line. A studio switching monitor in addition to a master monitor would be necessary in such a set-up: this is more than most stations which have installed this equipment have been able to provide.

A second and more common method of cutting to a superimposure is as follows: One of the pictures to be superimposed is preset on the fading bus which is not in use. The other is switched onto the fading bus which is in operation and at the same instant the two fading handles are set halfway.

There is a foolproof interlock on the two fading buses which makes it impossible to preset a camera on one bus if it is already in use on the other. This interlock may help avoid a few errors, but it renders impossible a method of cutting to a superimposure described in connection with the RCA studio switching system. One cannot cut to a superimposure by punching similar buttons on both sides, setting the fading handles halfway and punching two buttons at once.

Each of the manufacturers designed the present switching equipment and production consoles two or more years ago. Each based its design on the observed production procedure at its own broadcasting studios; General Electric at WRGB in Schenectady, Dumont at WABD, and RCA at NBC. Production procedures vary from station to station and these differences between the manufacturers' testing grounds produced in large part the variation in the operating equipment just described. As new kinds of equipment are devised and tried out, a closer standardization can be expected. With the exception of patented features the future models of all three manufacturers can be expected to approach a standard design.

Color Temperature: Its Use in Color Photography

By O. E. Miller

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Summary—Color temperature as a specification for light sources is inadequate to define any light source for color photography which departs appreciably in energy distribution from the black body. It should probably be restricted to use with tungsten incandescent lamps only. Meters devised to measure color temperature by means of measurements of the relative energy in two wavelength bands are likewise not trustworthy when applied to any but the black-body sources. A "three-point," rather than a "two-point," meter is needed for the precise control of photographic exposures. Such a meter should have sensitivity distributions that match those of the three emulsion layers of the color film.

Many important sources of light, such as the sun and the incandescent lamp, belong to a class, sometimes referred to as temperature radiators, which emit light due to high temperature. The ideal temperature radiator, from which the concept of color temperature is derived, is known as the black body, or complete radiator. It follows from the theory of the radiation from hot bodies, that a body which is a perfect absorber is also a perfect radiator. From theoretical considerations it is possible to calculate the amount of light of any wavelength that will be emitted by a black body at any given temperature. As the temperature is raised, an increased proportion of the energy is radiated at the shorter wavelengths, and the color changes from red through orange, yellow and white, to blue at a very high temperature. This series of colors forms the basis of the color temperature scale. It is important to note that many colors are not found on this scale and hence light sources having colors not matching the color of a black body cannot be expressed in color temperature. Examples are green, purple, magenta, violet, etc.

Both the color and the energy distribution of a black body are known, once the temperature is specified; hence, when applied to practical sources, color temperature can refer to either or to both of these two aspects of the source. The definition of color temperature adopted by the Optical Society of America[1] refers to the color alone

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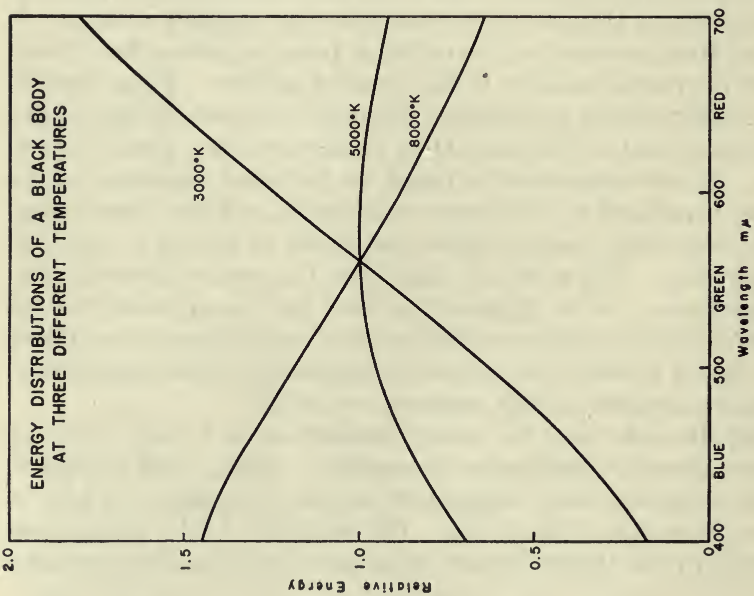

Figure 1.

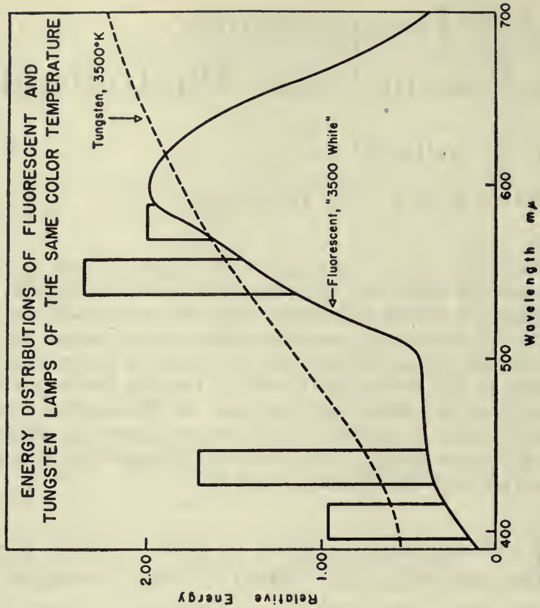

Figure 2.

and this definition has been generally accepted.[2] The color temperature of a light source may be defined as the temperature of a black body that matches the color of the source in question.

It is a property of color vision that sources of many different energy distributions may appear exactly the same color. Furthermore, it can be demonstrated easily that the suitability of a source for the illumination of colored objects is determined more by its energy distribution than by its color. Hence, unless the source has a known energy distribution, the color temperature specification is not usually sufficient to describe the most important aspect of the source. The energy distribution curves of Fig. 1 are characteristic of those of a black body. The temperatures are expressed in the absolute scale, in degrees Kelvin (°C + 273). Many familiar practical sources of light such as the tungsten incandescent lamp, not only match the color of a black body, but even have nearly the same energy distribution, although the actual temperature may differ from the color temperature. A tungsten filament, for example, may have a color temperature of 3000 K when its actual temperature is 2970 K. The candle flame is another example of a light source which closely resembles a black body both in color and in energy distribution. Such sources may be specified sufficiently well for most purposes in terms of color temperature alone because the energy distribution is known to be similar to that of the corresponding black-body source.

Many other sources, however, have energy distributions that are very different from those of a black body, although they may match the color of a black body at some temperature. An example is the fluorescent lamp. Illustrated in Fig. 2 is the energy distribution of a fluorescent lamp known to the trade as "3500 White," compared to that of a tungsten lamp operating at a color temperature of 3500 K. While these two sources in themselves have nearly the same color, the colors of familiar objects often look quite different under them. These differences in appearance are due to the differences in the energy distributions. The practical problems created by such differences in energy distribution are recognized by meat dealers, for example, who have observed the unfavorable dark red appearance of choice meat when illuminated by fluorescent lamps. Diners in restaurants also have objected to the greenish appearance of egg yolks.

If the source departs radically from the energy distribution of a black body, then a color temperature specification is of questionable

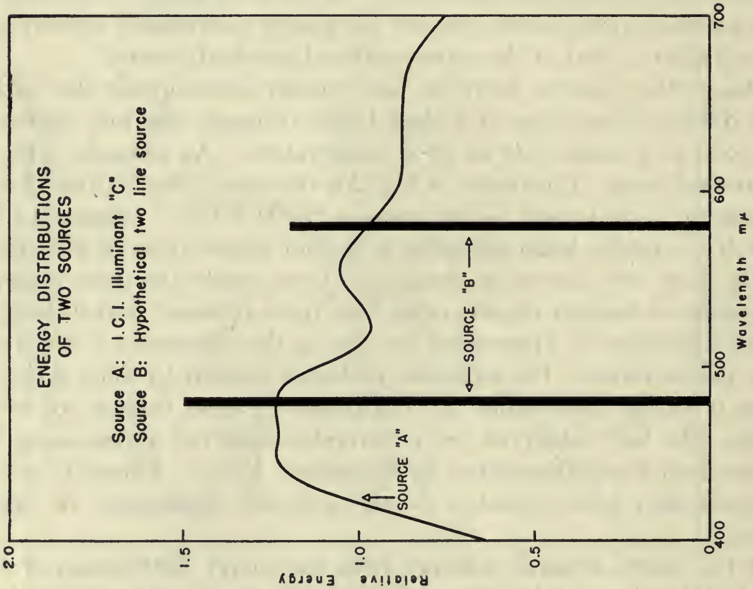

Figure 3.

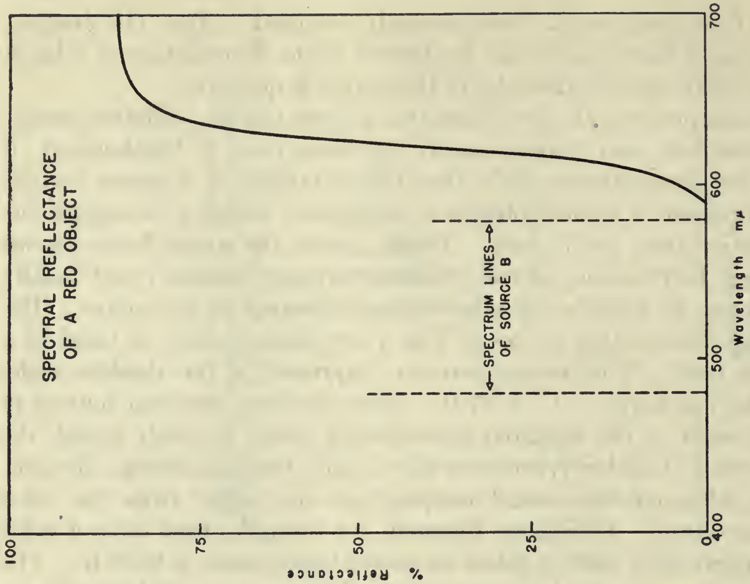

Figure 4.

value. The color temperatures of the two sources illustrated in Fig. 2 are the same; so color temperature in this case fails to distinguish between a good source and one which is much less suitable for the illumination of certain colored objects. Some authorities[3,4,5] are already giving serious consideration to the complete abandonment of color temperature as a specification of light sources, or at least restriction of the use of such specifications to tungsten incandescent lamps alone. Jones[3] suggests the use of the true temperature as an index of the spectral distribution of radiant energy from tungsten lamps. The important point to be recognized is that color temperature is a *color* specification, and as such it is inadequate to describe any but a very restricted class of artificial sources, principally tungsten lamps. It is inadequate because it fails to describe the most important aspect of the source, its energy distribution.

The inadequacy of a color specification for light sources may be further illustrated by an even more striking example of the effect of the energy distribution of an illuminant on the appearance of a colored object. While we usually consider white light to consist of a mixture of light of all the wavelengths of the visible spectrum, it is a well-known property of color vision that white also can be simulated by a mixture in the proper proportion of lights of only two, or at most, three wavelengths. Two such wavelengths are called complementary wavelengths. Consider two sources, then, with energy distributions such as those illustrated in Fig. 3. Both of these sources would look substantially white to a normal observer. They have the same color temperature. Source A is the standard I.C.I. (International Commission on Illumination) Illuminant C, and is similar to one phase of daylight; hence, objects appear in their normal colors under source A. Source B, however, contains light of only two wavelengths, one in the yellow, the other in the blue. Let us consider, now, the differences in the appearance of some typical colored objects under these two sources.

The color of an object results from the selective reflection, absorption or transmission of the light of various wavelengths falling on its surface. Thus a red object may reflect only the red wavelengths and absorb light of all the remaining wavelengths. This property of a surface may be represented by a curve such as that in Fig. 4, which shows the percent of the incident light that is reflected by the surface of a red object at each wavelength of the spectrum. When the light from any source falls on a colored surface, it gives rise to reflected

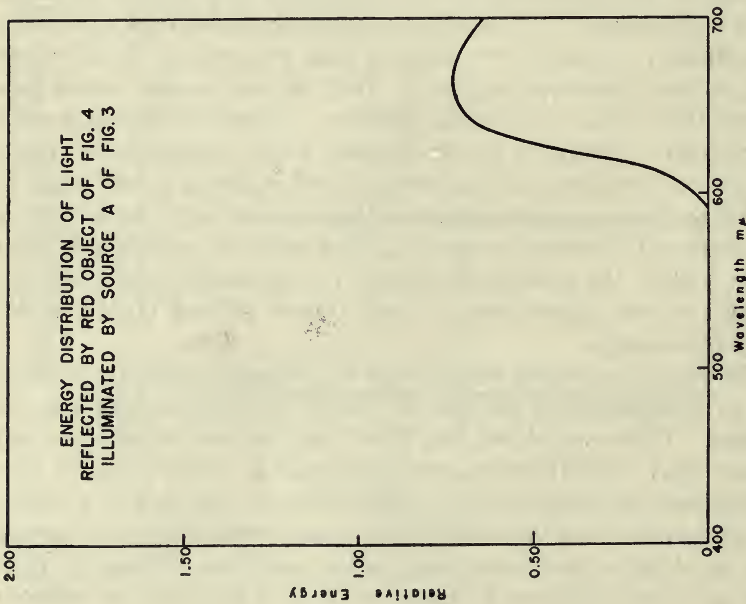

Figure 5.

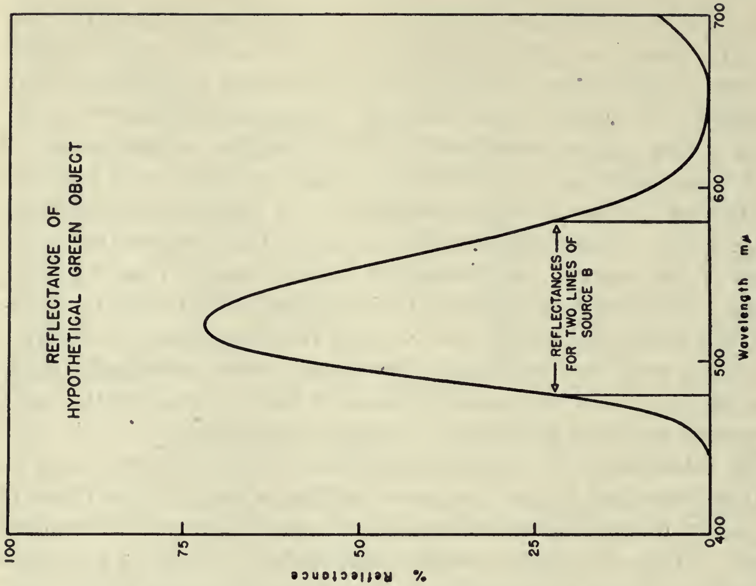

Figure 6.

light which generally has an energy distribution different from that of the source. It is the energy distribution reaching the eye from the object that defines the resulting color stimulus. This energy distribution may be obtained for the red object under source A by multiplying the ordinates of the curve in Fig. 4 by the ordinates of the energy distribution curve for source A in Fig. 3. The resulting energy distribution reaching the eye from the red object is shown in Fig. 5. Since only the red wavelengths are reflected, the object appears red. For source B, however, there is no red light from the source but only blue and yellow, both of which are absorbed by the red object, so no light at all is reflected and the red object appears black. By similar reasoning, it is possible to show that with the same source other objects may appear yellow, blue or neutral, depending on their relative reflectances for blue and yellow light. Figure 6 is the reflectance curve of a green object. Since the reflectances of this object for the two lines of source B are equal, the object appears the color of the source or neutral gray. While our example, source B, represents an improbable extreme, it differs in degree only from many practical sources. Some fluorescent lamps have a deficiency of energy in the red region which is balanced by a corresponding deficiency in the complementary wavelengths, the blue-green. Also there is an excess of energy in the yellow and green which is balanced by an excess in the complementary wavelengths, the violet. Lamp manufacturers are aware of these deficiencies and are working steadily for the improvement of commercial fluorescent lamps.

Commercial processes of three-color photography employ films having three sensitive emulsion layers with spectral sensitivities somewhat similar to the sensitivities of the color receptors of the eye. Hence color photography is almost exactly analogous to color vision in this respect. Color adaptation, by which familiar objects tend to retain the same appearance whether viewed by tungsten light or daylight, is, in the end result, analogous to the use of color correction filters with the color film so that objects photograph the same color by different light sources. And with color photography, the energy distribution of the source is just as important a factor in the appearance of objects as it is in vision.

It is customary, because of the convenience, to specify tungsten studio lamps in terms of the color temperature for which the film is balanced. Thus, Kodachrome Professional Film Type B requires a color temperature of 3200 K. Lamp manufacturers supply lamps

that will operate at approximately this color temperature when burned at their rated voltage. Since tungsten lamps change in color with age, changes in line voltage and blackening of the glass envelope, color photographers have had a real need for some means of checking the color temperature of their lamps. To supply this need, color temperature meters are now available. If voltage control is provided for in the studio, a color temperature meter offers a guide for the adjustment of the lamp voltage to obtain the proper color temperature. If the lamp voltage cannot be adjusted, the meter reading may indicate when a color correction filter is needed.

Several color temperature meters are designed to measure color temperature in terms of the ratio of the energies in two separate wavelength regions of the spectrum and are calibrated either to read color temperature directly, or to read in terms of the color filter required. It is assumed that the energy distribution is of the black-body type, and hence the readings are liable to serious error if the distribution departs seriously from that assumed. This limits the usefulness of such meters almost entirely to tungsten incandescent lamps.

Unfortunately, some of these meters may be used with daylight. But a color temperature specification of daylight is difficult, because the energy distribution of daylight departs considerably from that of a black body. This does not mean that daylight is an unsuitable source for color photography, but rather that it does not match a black body in color and therefore cannot be specified accurately in terms of color temperature. Daylight is made up of a mixture of varying proportions of sunlight and skylight. While sunlight alone, or skylight alone, are rough approximations to black-body radiation within the visible spectrum, mixtures of the two are not, since an additive mixture of the radiation from two black bodies of different temperatures will not match a black body at any temperature. Figure 7 illustrates this point by showing one mixture of the radiation from two black bodies operating at 2000 K and 20,000 K, respectively. A mixture somewhat resembling this might be encountered in late afternoon when the sun is quite red and the sky a bright blue. Also shown is the energy distribution of a black body at 3000 K. A color temperature meter based on measurements of the energies at wavelengths 520 and 690 mμ would indicate that the mixture was equivalent to the black body at 3000 K, whereas it has much more energy in the blue and red and less energy in the green than the 3000 K black body. The mixture is

quite pink and very far from matching a black body at any temperature.

In view of the departures of daylight from black-body radiation, which are neither constant nor systematic, there is some room for doubt as to the usefulness of a color temperature specification in connection with daylight, and existing color temperature meters may

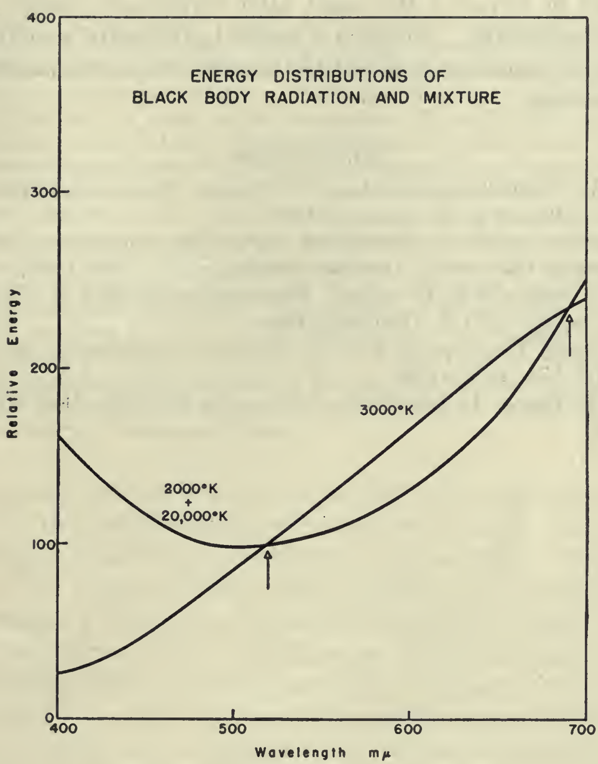

Figure 7.

give very misleading results. For many purposes satisfactory exposures can be made in daylight without any color compensation, provided exposures are avoided during the hours of early morning and late afternoon. At such times results are often unsatisfactory anyway unless the object is to record the sunset or sunrise effect itself.

In some applications of color photography precise control of daylight exposures may require that occasional filter corrections be made

for the normal variations in the quality of daylight. Since it is the relative exposure of the red, green and blue records in the film that determines the color balance of a picture, a meter is needed which is capable of measuring the amounts of energy in the red, green and blue regions of the spectrum. Ideally, such a meter would have three sensitive elements with spectral sensitivities like those of the three emulsion layers of the color film. The three readings could then be interpreted in terms of the exact filter corrections needed to give a balanced exposure. For such a meter to be useful a minimum of computation should be required to translate the meter readings into filter corrections.

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An Experimental 35-Mm Multilayer Stripping Negative Film

By JOHN G. CAPSTAFF

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Summary—The so-called "three-strip" method is generally considered to give the best results when taking professional color motion pictures. An objection to this method is that it requires the use of a special camera fitted with a beam-splitter prism. This paper describes work that led to the development of a single multilayer negative film which can be used in any standard motion picture camera. After exposure and before development, the two upper layers are wet-stripped separately onto special transfer supports. Thus the single support of the multilayer film bears three color-sensitive emulsions in the following order: a red-sensitive layer next to the support, an intermediate green-sensitive layer, and an upper blue-sensitive layer. The red- and green-sensitive layers, and the green- and blue-sensitive layers are each separated by interlayers which facilitate stripping of the two upper layers. The film has an over-all thickness about the same as standard motion picture negative film. Its speed is such that good negatives of an open landscape can be exposed at *f*/8 or even *f*/11. An experimental stripping machine is described which accurately registers the perforations of the two stripped layers with those of the original film on which remains the red-sensitive layer.

It is generally acknowledged in the motion picture industry that the method of taking professional color motion pictures that has given the best all-around results is the so-called "three-strip" method. The separate films, after exposure, are developed in a regular negative developing machine, resulting in three excellent original tricolor negatives. An objection to this method is that a specially designed beam-splitting camera must be used. The question came to mind: Would it be possible and practical to design a single film which could be used in any standard motion picture camera, with regular optics, and which, after processing, would give a set of original tricolor negatives of quality comparable to those made by the three-strip method? One answer seemed to be a stripping film.

Late in 1940 experiments were started on the design of such a film on which a single support would bear three color-sensitive emulsions, the first layer next to the support being red-sensitive, the next layer green-sensitive, and the top emulsion blue-sensitive. Between

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the red-sensitive layer and the green-sensitive layer would be a special interlayer having the property of adhering to the emulsions when dry but readily coming apart when wetted in water. It was thought that hydrolyzed cellulose acetate of a suitable acetyl content would probably meet these requirements. An interlayer of the same type would separate the green-sensitive emulsion and the blue-sensitive emulsion layers. Because of the fact that the green-sensitive layer and the

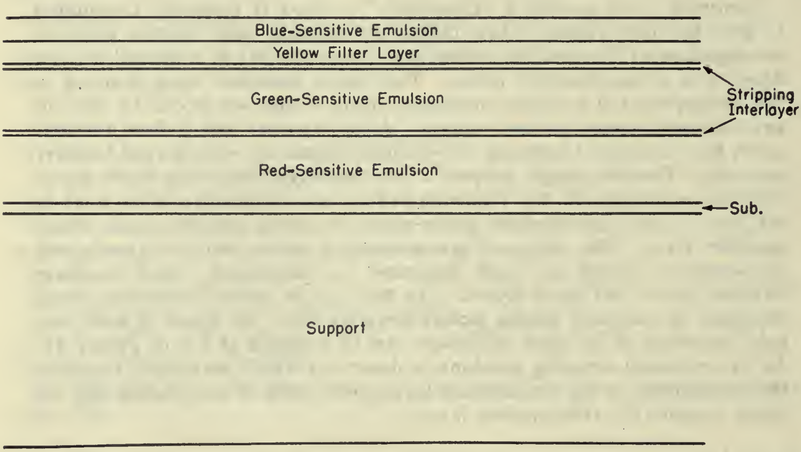


Fig. 1. Cross section of multilayer stripping film showing relative position of emulsion layers, filter layer and stripping interlayers.

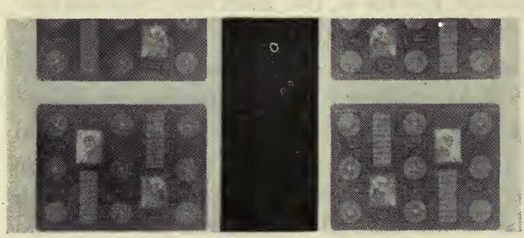


Fig. 2. Sample negatives obtained with early experiments.

red-sensitive layer are also sensitive to blue light, it would be necessary to interpose a yellow filter layer between the blue emulsion and the green emulsion (Fig. 1).

In the first experiments, a two-layer film only was attempted, since obviously if a single stripping operation could not be done successfully, satisfactorily stripping the more complicated triple layer would be highly improbable.

On February 6, 1941, exposures of a resolving-power chart were made in a Mitchell camera on such a two-layer film. The stripping was done before development on a simple machine on which the strippable emulsion layer was transferred onto a special transfer film bearing a suitable substratum. There was no pretense at maintaining registry between the two images, which, of course, must be accomplished for motion picture making. Figure 2 shows actual samples of these first negatives.

The technique of stripping was simple. The two-layer film was wetted in plain water, temperature approximately 70 F, for about 10 sec, and while under water was brought in contact with the transfer film; then the two films were rolled into intimate contact between two rubber-covered rollers. The "sandwich" was then allowed to remain for about a minute in order that the emulsion layer about to be stripped could bond to the transfer film. The actual stripping operation was performed over two rollers. After drying the film, development was performed in the conventional way.

About this time a blue-sensitive emulsion, bearing on its surface a yellow filter layer, was coated on a separate film. This made bipack experiments possible. Quite a bit of this bipack work was done on 4 x 5 in. and 5 x 7 in. sheet film, the bipack being exposed in a camera having a sheet of plain glass in the film holder. Some useful experiments were carried out in this way insofar as the emulsion properties were concerned, but the scheme was soon abandoned as far as serious picture making might go, because of the many defects in the negatives, such as Newton rings, dirt and halation.

Soon after this, a crude 35-mm machine was assembled which permitted stripping some film in which the perforations of the two-layer film were held in precise registry with the transfer film during the bonding period.

Color prints from these two negatives were made on a contact registering printer. The prints were found to be in good registry and no signs of distortion of the stripped emulsion layer were evident.

After this encouragement, a three-color multilayer film was attempted, but it was not until July 29, 1942, that a successful three-color coating was available for camera tests. The over-all thickness of this multilayer film was approximately the same as a black-and-white motion picture negative film. The sensitometric characteristics were excellent, all three emulsion layers having an exposure lati-

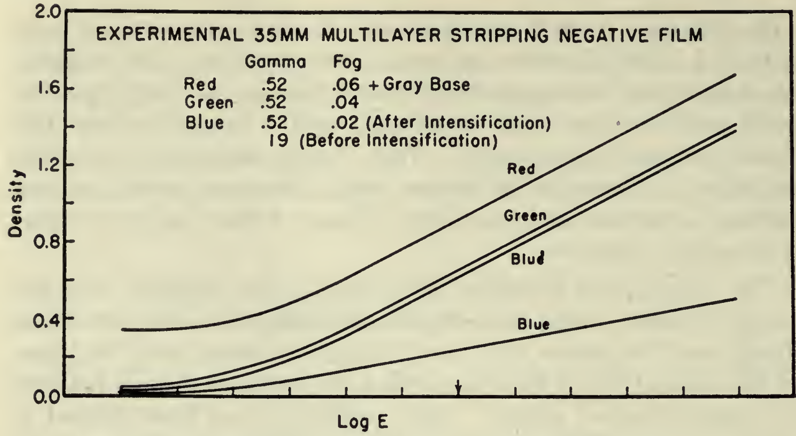


Fig. 3. Typical sensitometric curves for the three layers of multilayer stripping film.

Fig. 4. A typical set of multilayer stripping film negatives.

tude comparable to that of regular negative material (Fig. 3). The speed was such that good negatives of an open landscape could be made at $f/8$ or even $f/11$. The keeping properties of the emulsion layers equaled those of regular black-and-white emulsions. Because of the thinness of the three emulsion layers, the gammas were on the low side, the red- and green-sensitive layers giving a gamma of about 0.55, and the blue-sensitive layer still lower, being approximately

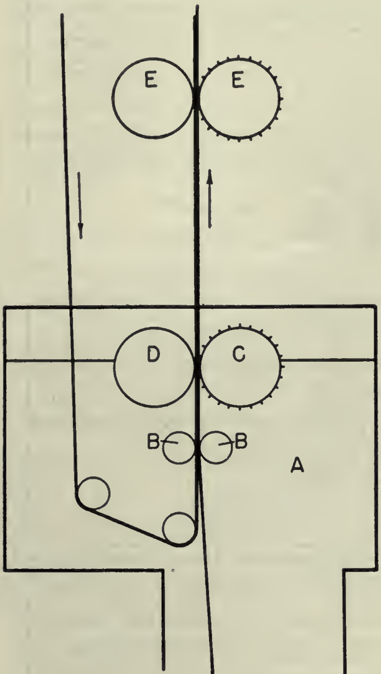


Fig. 5. Schematic section of machine showing rolldown registering station.

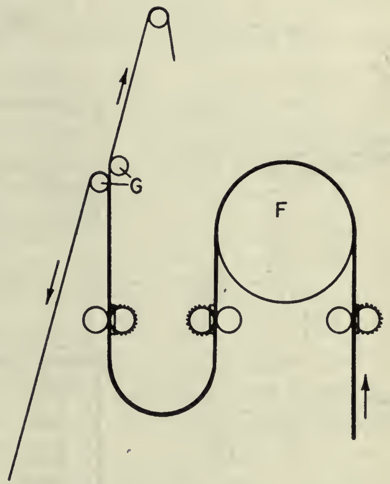


Fig. 6. Schematic section of machine showing stripping station.

0.30. The blue-sensitive layer was purposely made with a low silver halide density in order to interfere as little as possible with the resolving power of the two underlying emulsion layers. For most printing processes this necessitated either intensifying the blue negative or making a "dupe" having the desired over-all gamma.

When working out a motion picture film, it was considered important to succeed in stripping prior to development in order to avoid defects arising from depth development. As is well known to those

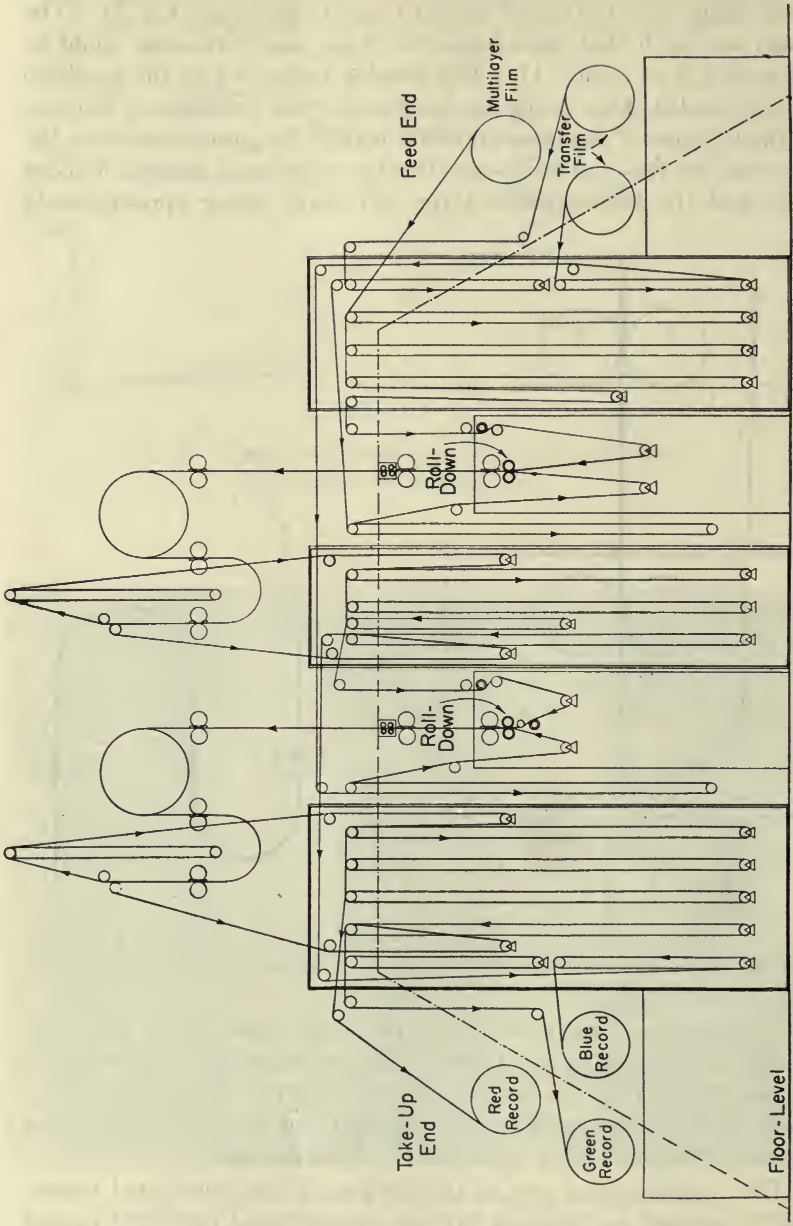


Fig. 7. Kodak multilayer film-stripping machine.

working with material coated in several layers, these defects can be quite serious. The defects are caused mainly by the reaction products in the lower layers diffusing to the upper layers. Another advantage in stripping before processing is that a certain measure of gamma control is possible by regulating the amount of development in the usual way.

Good progress was being made both in the manufacturing end and in the processing end. Many thousand feet of tricolor film were stripped, developed and printed, although the process could not yet be regarded as ready for the market. The photographic quality of the negatives was of a high order of excellence (Fig. 4) and obviously could be used in any of the known color printing processes.

During the war years, work on the preparation of coatings was practically brought to a standstill, though worth-while efforts were continued in other directions, particularly in the design of a registering-stripping machine. After two or three machine designs had been tested and rejected, the basic principles on which a practical machine could be built were established and practical experimental work was done as circumstances permitted, ending in the construction of a machine, the essential parts of which are shown schematically in Fig. 5.

In the figure, *A* is a tank of 70 F water in which the multilayer stripping film and the transfer film are wetted for approximately 10 sec. The two films meet at the rubber-covered wringer rollers, *B*, where they are rolled into intimate contact. Four inches farther on, the perforations of the two films are brought into accurate registry by means of a specially designed sprocket, *C*, and a socket roller, *D*. The sprocket roller, *C*, is positively driven at the film speed of 30 fpm. Since the perforation pitches on any two films are never exactly alike, it is necessary on the machine to keep the shorter-pitched film stretched to match the pitch of the longer one during at least part of the bonding time. This is accomplished by means of two other sprocket-socket roller assemblies, one of which is indicated in *E*. These two sprockets are friction clutch-driven and have an overdrive of approximately 5%, thus maintaining the required tension. The distance between the registering sprocket and the first overdriven sprocket is 18 in., and it is 48 in. between the first overdriven and the second overdriven sprocket.

By the time the film arrives at the second overdriven member, the adhesion between the emulsion and the transfer film is such that the

Fig. 8. Hand-stripping of multilayer film.

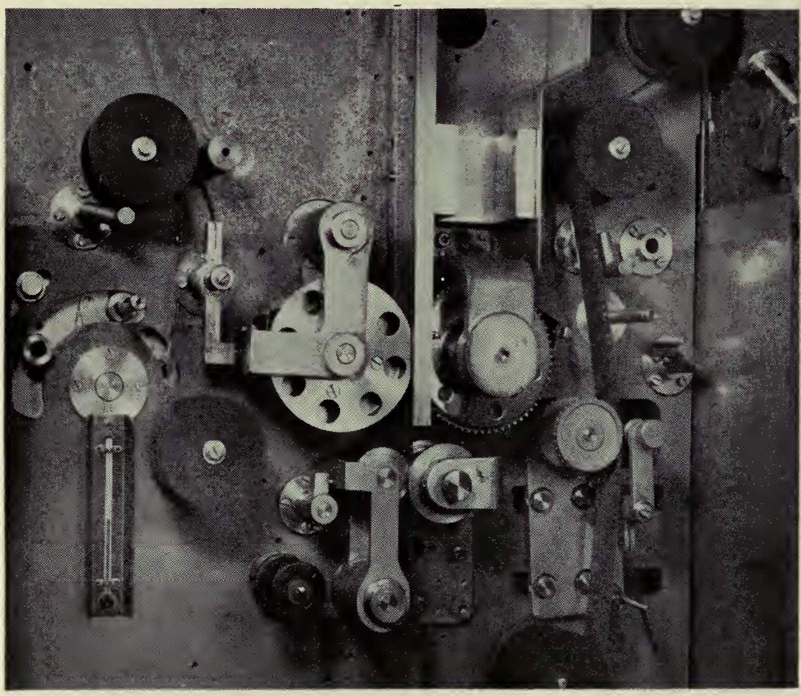


Fig. 9. Close-up of stripping machine showing rolldown registering station.

films can continue on their path without being under tension, although the bonding is not firm enough for stripping.

In Fig. 6 the "sandwich" next is seen passing over a sheave, *F*, then down into a loop, and finally up to the two simple stripping rollers, *G*. After parting company, the two films pass through a drying cabinet of conventional type from which the stripped emulsion passes on to a regular take-up at the end of the machine (Fig. 7), while the red-plus-green multilayer film, when dried, continues on to a second wetting, rolldown, registering station, and is stripped in the same manner as the blue-emulsion layer. The red-sensitive emulsion remains on the original support. After these two films are dried in a second drying cabinet, they are also taken up at the end of the machine. Development is done on another machine.

In Fig. 8 a small piece of film is shown being stripped by hand. Figure 9 is a close-up photograph showing in detail the important rolldown registering station on the stripping machine that was sketched in Fig. 5. In the photograph (Fig. 9) is seen a straight film track. It is important that the films, when registered, move on through the machine in a straight line until the adhesion is sufficient to prevent slippage occurring between the two films. As previously mentioned, this state is reached immediately after the film has reached the second overdriven sprocket. The track serves to maintain the film in the required straight path and also acts as a means of stripping the films from the registering sprocket. The purpose of many of the other details in the photograph will be easily understood by film-processing engineers.

NOTE: At the conclusion of the paper, a short motion picture was shown which demonstrated the method of stripping the multilayer film, first by hand using small pieces, then by the registering and stripping machine with long lengths of film.

Printing Equipment For Ansco Color Film

By F. P. HERRNFELD

Ansco, Hollywood, Calif.

Summary—The Scenetester takes the place of a cinex machine in manufacturing Ansco Color prints. Its primary function is to make it possible for the timer to select for a given color original or dupe the proper color correction filters and printing density. The Scenetester must match the printer or printers it is teamed with for absolute light output, color balance, exposure time and light changes. This paper describes a Bell & Howell Model D printer modified for color printing and a Scenetester which was made for darkroom operation. The Scenetester prints 16 frames simultaneously through 16 different color correction filters and was designed to work with modified Bell & Howell Model D printers.

The printer modification consists of adding a new lamphouse, and the installation of an automatic filter changer (Fig. 1). The filter changer works on the principle of a slide projector. The individual filter packs are mounted in semitransparent filter holders and are stacked in the proper sequence in a feed magazine. The contactor originally operating the semiautomatic light-change mechanism and light-card indexer is employed in this modification to activate also the solenoid of the filter changer. For every light change, a filter slide change automatically takes place, whether or not a filter change is necessary.

Figure 2 shows the optical system employed. The light source is a standard 750-w, 120-v, T-12 pre-focus projection-type lamp. In operation this lamp voltage is adjusted to approximately 95 v, giving it a color temperature of about 2900 K (degrees Kelvin). This low color temperature increases the life from the rated 50 hr to about 1600 hr.

A condenser focuses the filament of the lamp in an objective lens. The objective lens in turn focuses a plane in the condenser on the ground glass of the Bell & Howell printer, located at the aperture of the light-change mechanism.

A fire shutter is located between the lamp and the condenser. A

Presented: October 11, 1949, at the SMPE Convention in Hollywood.

filter holder is located on the other side of the condenser in the least intense part of the light beam. This filter holder accommodates the emulsion correction filters, an Aklo heat absorbing glass, and an Ansco UV-16 printing filter. Part of the forced air for cooling the printing light is directed over this filter pack.

SCENETESTER

The basic elements of the Scenetester are a light source, optical system, a calibrated light-change mechanism, a curved platen for 16 color correction filters, means for holding the camera film over the platen and a printing film stock carriage. The lamp receives its power directly from an a-c line through a voltage regulating transformer. The color temperature of the light is set by a variable transformer (variac), with an a-c voltmeter connected directly across the terminals of the lamp. Forced air ventilation is provided for the lamp and the emulsion color correction filters to permit continuous operation of the lamp.

The optical system of the instrument is similar to that of the printer modification, particularly the light source and lens system (see Fig. 3). A rotating mirror, mounted on a shaft driven by a synchronous motor and centered with the axis of the lens system, deflects the light beam from the objective lens through an angle of 90°, and causes it to scan the curved printing platen. The lengthwise centerline of the platen aperture is aligned with the axis of the rotating beam.

The mirror is fastened inside a tunnel to keep stray light from falling onto the film. An adjustable aperture is located on the end of the tunnel within 1/4 in. of the camera stock being tested. This aperture may be adjusted to give any exposure between 1/10 and 1/50 sec to match the exposure time of the printer with which it is teamed. With a Bell & Howell printer running at 60 ft per min, the exposure time is set for 1/48 sec.

The length of the platen opening is slightly over 12 in., accommodating 16 single-frame color correction filter combinations. The radius of the platen is such that the camera and printing films are engaged over an arc of 140°.

Two exposure platens were made for each instrument. One of the platens was furnished with the color correction filter packs shown beside Fig. 4, each filter combination covering one 35-mm frame. Such a platen is now being used for making scene tests.

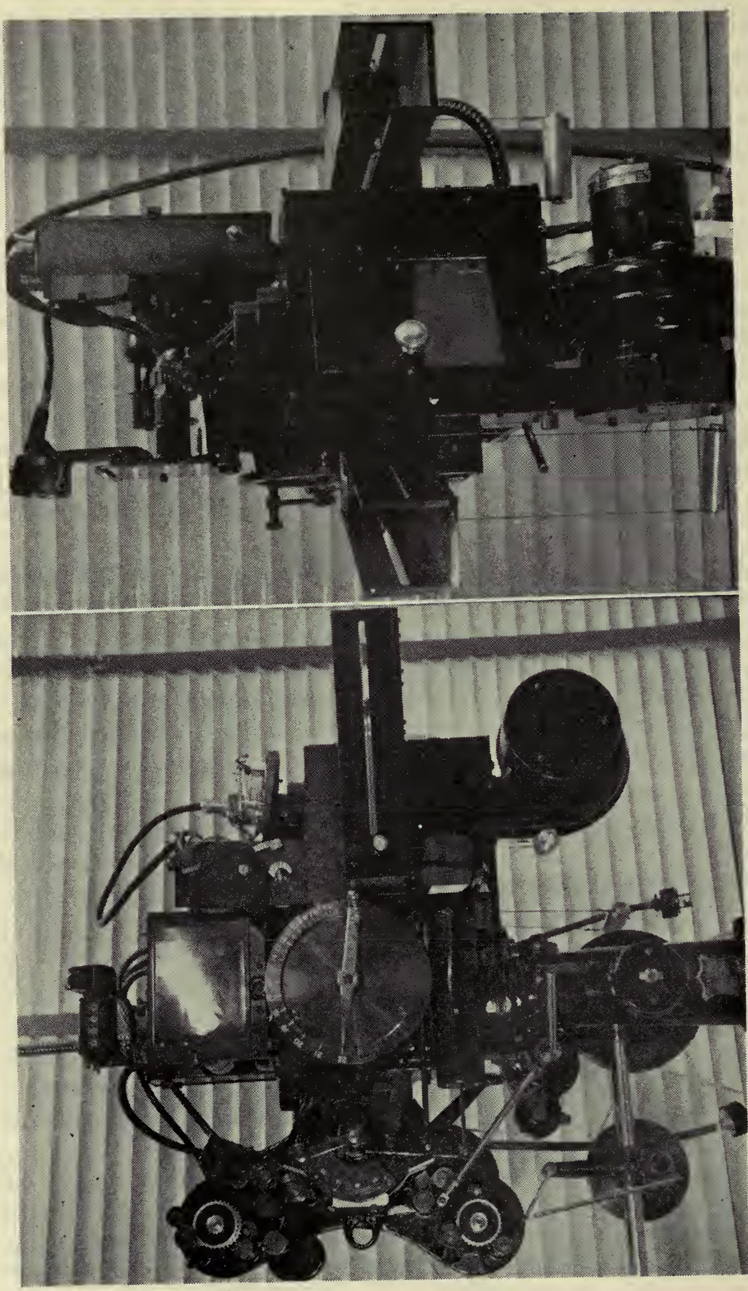


Figure 1.

Color correction filters come in three series:

1. The yellow series (20), which absorbs blue and transmits green and red.

2. The magenta series (30), which absorbs green and transmits blue and red.

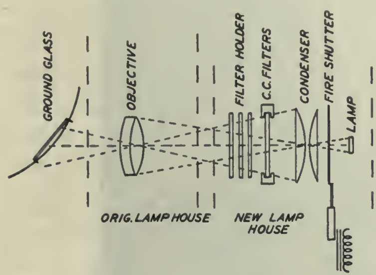


Fig. 2. Modified Bell & Howell Model D printer optical scheme.

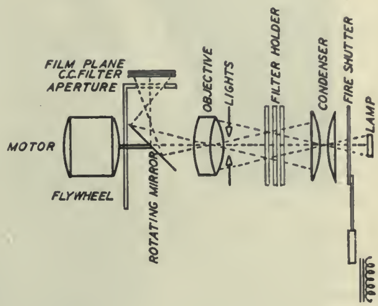


Fig. 3. Scenetester scheme.

Frame	*Color Filter*	*Frame*	*Color Filter*
1	None	*11*	1 – 24
2	1– 24		1 – 25
3	1 – 24		1 – 34
	1 – 34	*12*	1 – 24
4	1 – 34		1 – 25
5	1 – 35		1 – 35
6	1 – 35	*13*	1 – 24
	1 – 24		1 – 25
7	1 – 35		1 – 34
	1 – 25		1 – 35
8	1 – 34	*14*	1 – 25
	1 – 25		1 – 34
9	1 – 25		1 – 35
10	1 – 24	*15*	1 – 24
	1 – 25		1 – 34
			1 – 35
		16	1 – 34
			1 – 35

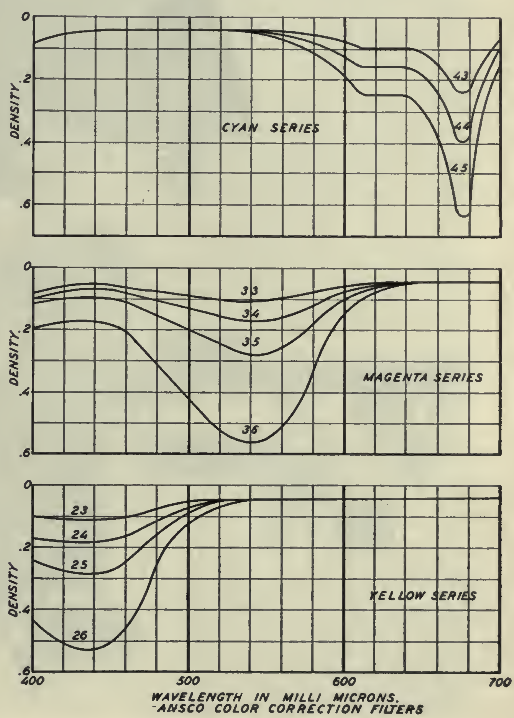


Fig. 4. Ansco color correction filters.

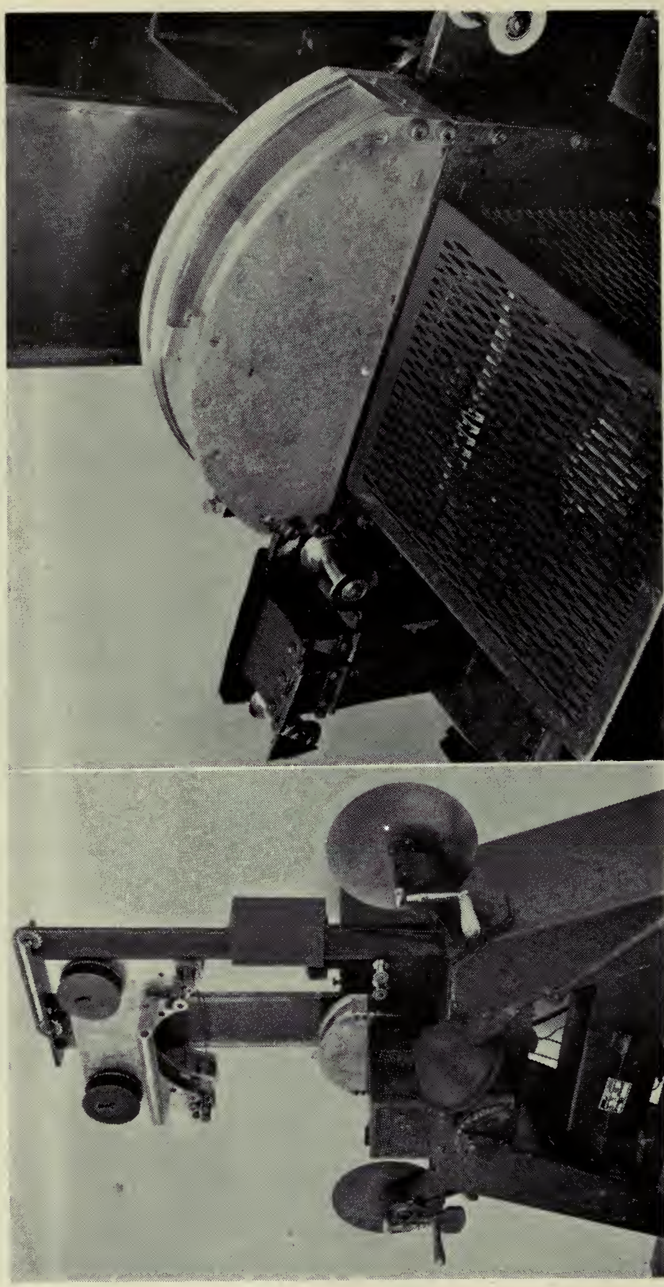


Figure 5.

3. The cyan series (40), which absorbs the red and transmits blue and green.

The numbering system is arranged so that 4 (*i.e.*, 24, 34 and 44) will give a reduction of one-half stop of light in printing value for Ansco Color printing films in the desired band. Numbers 3 denote $\frac{1}{4}$, 5 denotes 1, and 6 denotes 2 stops.

The curves in Fig. 4 show the insertion losses of these filters plotted in density versus wavelength.

From these curves it is evident that the least number of filters will give highest efficiency. For instance, one 24 will give $\frac{1}{2}$ stop correction in the blue end with only 15% insertion loss in the rest of the spectrum. Two 23's will give also $\frac{1}{2}$ stop correction but will increase the insertion loss in the rest of the spectrum to about $27\frac{1}{2}$%. With the amount of light used in printing color film this becomes a factor to be reckoned with. Filters of all three series should never be put into one pack because, for instance, one 24, one 34 and one 44 would act the same as putting a neutral density of approximately 0.15 into the light beam; however, one 26, one 36 and one 45 can be replaced by one 25 and one 35 with one stop more light available to the film.

The other platen was furnished with two methyl methacrylate resin (Lucite) window leaves $\frac{1}{16}$ in. thick. Sufficient room was allowed in the construction of the platen to place a neutral dye or silver step wedge between the two pieces of plastic. This platen is used to make intensity scale sensitometric strips.

The scene test and sensitometric platens are interchangeable without the use of tools during darkroom operation.

A filter holder for the emulsion correction filters, Aklo glass, and related items, is provided as in the printer. It is accessible during darkroom operation. Filters can be changed while the printing light is burning without fogging the raw stock.

The light-change aperture is located between the elements of the objective lens. It has 21 discrete steps, being separately adjustable to give a light change from $\frac{1}{12}$- to $\frac{1}{5}$-stop per step. The total range for the 21 steps can be adjusted to give from $1\frac{3}{4}$ to $4\frac{1}{5}$ stops variation from light 1 to 21. To assure that the flatness of field at the film is not altered when changing the light intensity, a ground glass was placed between the lamp and the condenser. The ground glass also makes placement of the filament of the lamp less critical. The illumination across the film width is uniform within $\pm 2\%$, while the illumi-

nation along the platen length is within ±3%. This uniformity was verified by film exposures.

The camera film to be tested is held between two rewinds. It is threaded through a viewing box, over the film platen and to a take-up. The viewing box is located to the left of the film platen, with light shields to permit darkroom operation. The primary function of the viewing box is to frame the camera original with the color correction filters in the platen. Sprockets, rollers and weighted rollers are arranged in such a manner as to allow easy threading in the darkroom with a minimum of danger to the camera film.

The printing film is mounted on a manually operated carriage which accommodates 400 ft of Ansco Color printing film raw stock (see Fig. 5). The spindles holding the film are made to take either negative or positive plastic film cores. The film is fed from the unexposed roll over a film sprocket, under a curved pressure plate, over another film sprocket, and onto the take-up spool. The two film sprockets are coupled by a chain-and-sprocket arrangement to assure a constant loop under the pressure plate. When the carriage is moved down into the exposure position, *i.e.*, at the point of contact between camera and printing film, a microswitch starts the exposure cycle. This cycle is completely automatic and has safety features preventing the exposure of less than a full platen, as well as double exposures. A contactor in series with the fire shutter also prevents accidental fogging of the film due to too early release of the carriage.

As the camera and the printing film are engaged over an arc, it is necessary to move the printing film vertically away from the camera film until the loop of printing film has cleared the camera film by at least ½ in. before the raw stock is advanced. Only after all physical contact between camera and printing film has ceased, will the automatic transfer of the printing film start. At each upward stroke of the raw stock carriage, at least 20 frames of printing film are transported onto the take-up spool. At the completion of the upward stroke, a contactor automatically resets the instrument for the next exposure cycle. If the upward stroke is not completed the fire shutter will not open upon contact of the printing and camera film.

Correlation Between Printer and Scenetester

In adjusting the Scenetester for the proper light and color temperature to match the color printer, a color temperature meter of the comparative type is an invaluable aid (see Fig. 6). A meter built for this

particular purpose utilizes a Weston Model 856 photovoltaic cell and a 200 microammeter having resistance of approximately 12 ohms. With this low resistance the meter reading will be practically linear with change in light intensity. Approximately 75 ft-c will give basically full scale deflection.

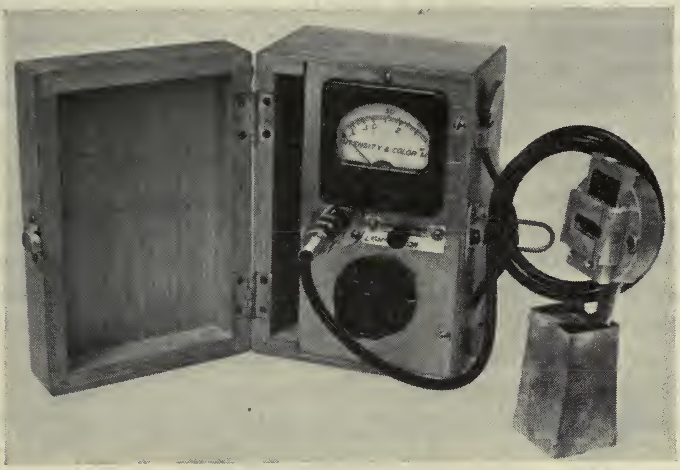


Fig. 6. Color temperature meter.

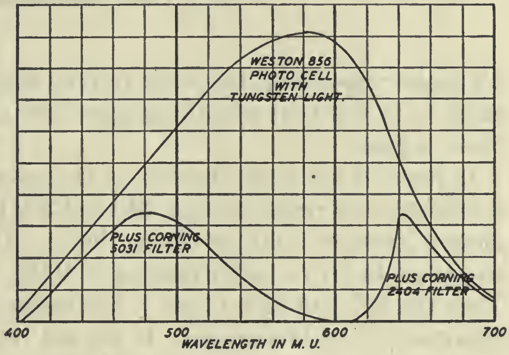
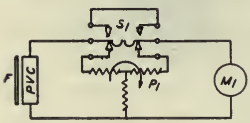


Fig. 7. Relative sensitivity of color meter and filters.

A neutral density and two filters are used in conjunction with the meter. The first is a fine grain silver density to reduce the light input to the photovoltaic cell by a factor of 5. The second filter is a blue-green Corning glass #5031, 5 mm thick. The third is a red Corning glass #2404, 2 mm thick. The transmission characteristics of the two color filters are shown in Fig. 7.

The filters are mounted in a slide holder which fits the gate casting of a Bell & Howell printer and which is provided with an adapter for use with the Scenetester. The aperture of the meter is made to take the full light output from either the color printer or the Scenetester. This slide holder has four positions. In the first position the light reaches the photovoltaic cell directly, allowing the meter to give a readable deflection at the lowest printer point. In the second position the opening is covered with the silver density reducing the sensitivity of the meter from 75 to about 375 ft-c. In the third position the opening is covered with the blue-green filter. With the slide in this and the next positions, a T-pad is switched into the electric circuit of the meter. This pad is for the purpose of adjusting the meter to 100%, the reference point for color temperature measurement. The fourth opening is covered with the red filter. The difference in reading between the two filters is the color temperature indication. The electric circuit of this color and light meter is shown in Fig. 8.



F_A Clear
F_B 0.70 neutral density
F_C Corning 2404, 2-mm filter
F_D Corning 5031, 5-mm filter
M_1 Weston 200 U.A.D.C. meter

PVC Weston 856 cell
P_1 15-ohm T-pad
S_1 D.P.D.T. switch

Fig. 8. Color meter scheme.

All measurements on the color printer and the Scenetester must be made with the heat absorbing glass and the Ansco UV-16 printing filter in place.

In practice the lamp rheostat of the color printer is adjusted until the light meter reads between 240 and 350 ft-c with the printer set to picture aperture and maximum light. After this adjustment the pad is set to give a meter reading of 100% with the blue-green filter. Then the red reading is noted. The meter should read about 80% in reference to the blue-green. If the red reading is higher than 80%, the lamp voltage is increased and the light output decreased by inserting some neutral densities such as a fine mesh screen, a ground glass, or for smaller changes, clear glass, into the optical system of the printer. If the red reading is lower than 80%, the lamp voltage should be lowered.

Measurements on the Scenetester are inverted. With a heat absorbing glass and an Ansco UV-16 filter in place, the color tempera-

ture is adjusted first and then the necessary changes are made to obtain the same light output as that of the color printer.

All measurements made with the light meter should be considered preliminary. The light-change mechanism should not be calibrated with the meter. The final check at about every third printer light must be made photographically. For this a test loop is made. The picture of the test loop should consist of a neutral gray scale. Each gray patch should be large enough to be measured with a color densitometer. This loop should then be printed on the printer and Scenetester every third light. From this test the light-change mechanism of the Scenetester should get its final adjustment. One or two reprints may be necessary before a complete agreement between printer and Scenetester is reached.

Conclusion

Two of the Scenetesters have been completed and have been in continuous use since they were finished, one for a period of over two years. Both of these units are teamed with modified Bell & Howell Model D printers. Thus far they have performed well with very little maintenance. They are checked on a daily routine basis for intensity and color temperature with the color meter.

16-Mm Film Color Compensation

By O. K. KENDALL

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Summary—Second generation color duplicates on 16-mm film are noted for problems of contrast and color fidelity. These deficiencies have been responsible for the widespread practice of printing from the original. Some experimental techniques and devices for the printing of special key* intermediates which tend to counteract these faults are explained.

During 1948, the greater part of 16-mm color release printing at the National Film Board of Canada was on Kodachrome duplicating stock printed from originals. Some productions were printed from masters, but nearly all such second generation material far exceeds the acceptable limits of contrast gain. Even duplicates printed from the original are seldom ideal in this regard.

The nature of documentary film shooting makes it impossible to assume that a given original is a standard to which all duplicates should closely correspond. Because of the quasi "candid camera" approach and the almost inevitable lighting difficulties, many scenes which are later cut together display a wide range of exposure and color deviations. To include all the necessary color and exposure corrections when release printing from such originals would be likely to involve too many operations to prove economical.

This report concerns an investigation into the possibilities of including color and exposure compensation plus counteracting measures against second generation contrasts in special 16-mm key film intermediates. Where relatively few such printing intermediates are required, it should not prove uneconomical to employ step printing, scene-to-scene color corrections, masking techniques and other custom-job methods. To this end, an early model 16-mm Depue step printer was rebuilt to provide independent timing for each color layer of the duplicating stock to be printed. Exact registration facilities for masking operations were added.

Various other auxiliaries were necessary. Timing viewer boxes were equipped with 3500 K (degrees Kelvin) light as an alternative to

* Throughout this report, "key" films refer to intermediates made by the methods to be outlined.

Presented: April 8, 1949, at the SMPE Convention in New York.

the conventional yellow light source. Color filters peaked at the wavelengths used in the tricolor printer were fitted to a Western Electric densitometer for color timing tests. A wafer-thin selenium cell probe, connected to a 50-microampere meter, provided the basic correlation of the printing exposure in each primary color.

Before describing the tricolor printer, it is desirable to outline some of the corrections that it is believed a key film should possess for release printing service.

1. The key film should release print on one light.
2. The general color-casts of significant images should be maintained on a scene-to-scene basis.
3. The deviations in the relative transmissions of significant hues which occur in both first and second generation duplicates should receive a combined compensation in the key film.
4. The key film should exhibit reduced chromaticity if a hue shift in a high chromaticity color is inevitable.
5. A chromaticity increase should be available for scenes that were overexposed in the original.
6. Underexposed and shadow areas require sufficient relative density reduction in the key film to expose correctly the release print.
7. The general gray gamma of the key film should counteract the gamma gain of the release print to bring about a match with the contrast of the original.
8. The resolution of the key film images should not be materially lower than that of the original.

Other complementary parts of the program call for integration with the black-and-white standards in routine laboratory use. The background information for color timing judgment was based on printer loop tests. Additional color printing data and the terminology used have been extensively treated by Miller,[1] Offenhauser,[2] Hanson and Richey,[3] and Yule.[4]

Design of the Experimental Tricolor Printer

The design objectives of the experimental tricolor printer hinge on the provision of facilities to effect a maximum of the desirabilities for key films as outlined above. The step printer selected for modification provided the initial film handling and printing-gate facilities. The lamp-house shutter, lift cams, worm drives, master clutch and the sprockets were left unmodified. Extensive modifications were neces-

sary for the handling of color masks concurrently with the original and the raw stock. Independently adjustable clutch-drives power the three take-up rolls. All sprocket guide-rollers and other film pressure-plates are lightly spring loaded to prevent sprocket damage should any of the three films become misaligned. The alternating-current motor drive system was changed to a molded V-belt drive for greater speed constancy. The original drop-board of the pin-insertion type was discarded for a newer Depue slide-bar type.

In addition to the normal step-printing action, registration pilot

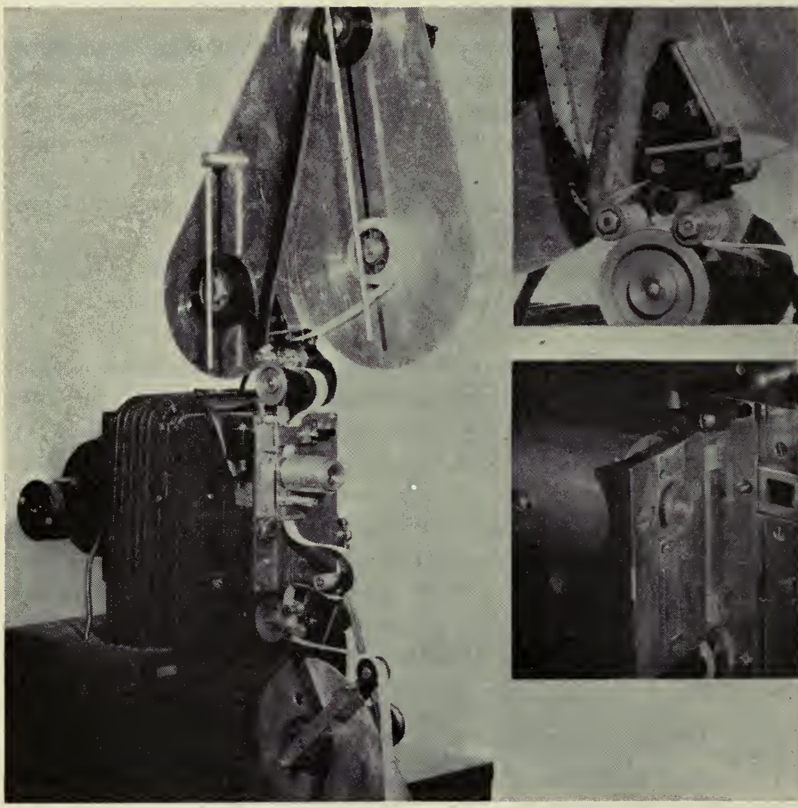

Fig. 1. General view of printer. Top insert shows shadow-flasher with raw stock route, while the "original" film (center) feeds down back-to-back to the notched masking roll at the rear. Lower insert shows view of pressure-platen and projecting registration pins. The cam-operated pins shown on each side of the printing aperture lift the registration pins and the platen in sequence when the gate is shut.

pins which span four sprocket holes were designed as part of the printer gate and viewer assembly. The pins were attached inside the viewer barrel to a spring-loaded slide-cylinder. A methyl methacrylate pressure-platen, separately spring-loaded, extends from the slide-cylinder. The platen was made slightly convex to improve the printing contact of the films at the center of the frame. Cam-operated lift-pins push the complete slide-cylinder assembly clear of the films during the pull-down operation (Fig. 1). The nonrigid pilot-pin design provides for registration between the various films which are separately aligned to the printer gate by an edge guide rail.

The original lamp house was stripped and a bakelite platform mounted in it about an inch below the printer-gate barrel. A triangular arrangement (Figs. 2 and 3) of lamp sockets is grouped on the bakelite. Ductile copper brackets extend behind each socket to form positionable supports for three concave mirrors. The mirrors were turned from solid duralumin and have a 2-in. radius of curvature. The light sources are three 16-v, 21-cp tail-light bulbs. Spring holders for glass-protected Wratten filters are provided in front of each lamp. The light beams from the two side lamp-and-mirror combinations are redirected toward the printing aperture by two flat rear-surfaced mirrors mounted in adjustable holders. Completing the lamp-house arrangements is a countersunk door on which is mounted a centrifugal fan. The air blast effectively cools the Wratten filters and the trilamp assembly, etc., and is exhausted through the bottom of the lamp house and over the timing resistance banks (Fig. 3).

It will be apparent that no provision for optical accuracy is present in these lamp arrangements. A very random direction and distribution of approximately 40 lm of tricolor light reaches the printing aperture entrance. The design postulates a light-integrating unit which is fitted in the printer-gate barrel to provide a uniform admixture of tricolor light at the film printing plane. The light-integrating unit is a parallelepipedon structure which is silvered externally on four sides. The general schematic design is shown in Fig. 2. The unit was constructed from $1/16$-in. sheet methyl methacrylate and sealed against dust. The total light transmission efficiency measured 75%. When visually observed through the printer gate, the unit presents a series of shifting color-casts due to the lenticular surfaces of its diffusion plates. However, regardless of the degree of irregularity in color intensity presented at the prism end of the unit, no fringing or measurable color deviations appear across a test frame when film is printed.

The arrangements for tricolor timing were designed for a minimum of change to the existing printing practices. The Depue drop-board solenoid gear was modified to drop the contact unit in steps of three at a time. Two additional contact brushes were added to make a triple contacting drop unit. The 22 riser-bars of the drop-board are connected by multiple cable and plug to three banks of adjustable tapped resistors located in the subcompartment on the printer (Fig. 3).

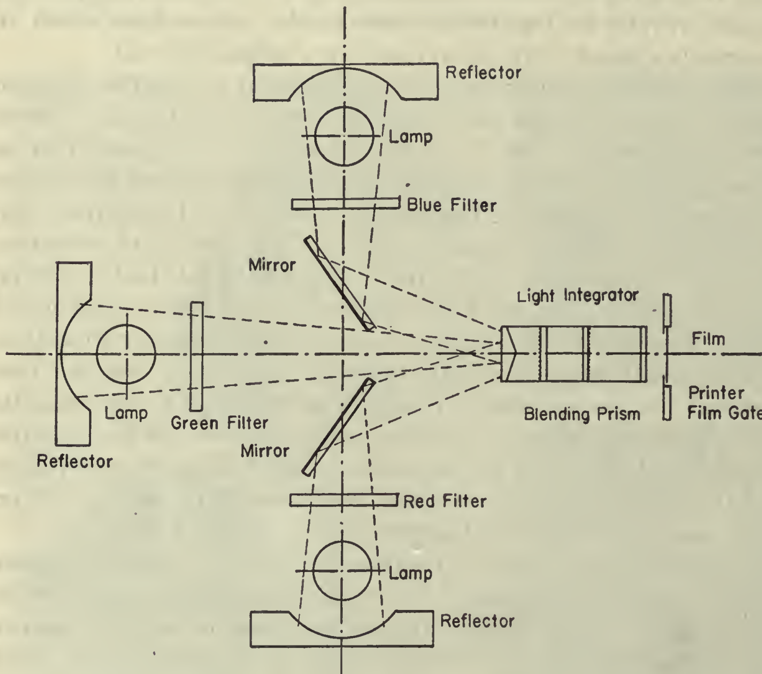

Fig. 2. Arrangement of the lamp-house components shown through the open door in Fig. 3.

Three heavy-duty rheostats provide over-all tricolor balance for top light adjustments.

The regular 22 printer lights per bar of the drop-board are divided into groups of seven. Each timing slide-bar can serve duty on any of the three colors. For convenience, sets of three consecutive slide-bars were assigned for the timing of red, green and blue, descending in that order. The timing card, as supplied to the operator, was also coded in triplets but no change to conventional operator practice is

required for the setup of the slide-bars on the board. The light changes are initiated by regular edge notches which are applied to the masking and timing film roll.

An extra triple-pole switch is located on the printer. It serves to connect the three lowest printer lights to the line regardless of the setting on the drop-board. Four of the riser bars on the board are not connected and are accordingly coded as zeros. This design provides for a minimum or "base light" connection so that all lamps may

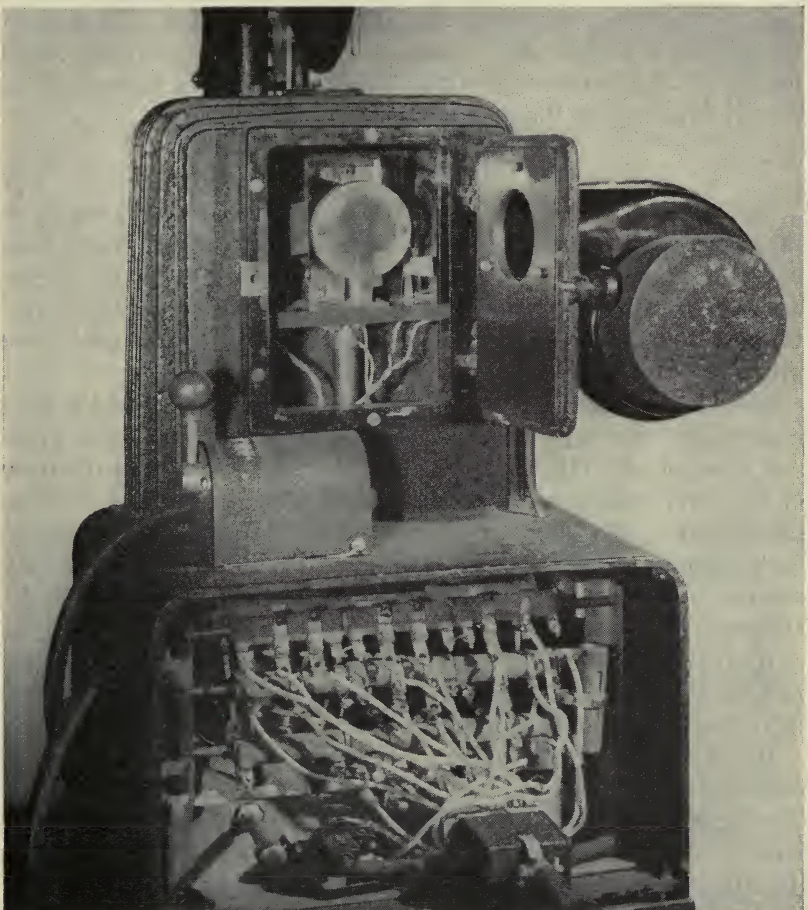

Fig. 3. Rear view of printer with the lamp-house door open. The three potentiometers shown below the adjustable resistance banks provide red, green and blue light control with the key shown in position on the "red" potentiometer.

remain lit during contact interruptions when the lights are "dropped." When the base light is off, it is possible, by a zero setting on the board, to print with the intense color of one or two of the three near-monochromatic lights.

A raw stock pre-exposing unit, called a shadow-flasher, is located just ahead of the feed-in sprocket. It consists of a light chamber, a miniature lamp, a Wratten filter holder, and a film guide channel. The lamp is under-volted and resistance-controlled. The raw stock is normally routed through the shadow-flasher before joining with the color original and the timing film at the feed sprocket. To prevent the fogging of a frame when printing is stopped, the printing control master clutch is interlocked with a safety switch in the flasher circuit. A manual switch for the shadow-flasher is also provided.

The Tricolor Printer Setup

The tricolor printer furnishes additive color correction. Owing to the narrow pass-bands of the color filters in use, it is possible to compensate effectively for changes in color temperature of the incandescent lamps when the timing resistor settings are determined. This timing advantage is not available with conventional single-pack color printers.

Each printer light change is preset to be about 70% of the next higher light. Seven printer lights are assigned to each of the red, green and blue colors. The three printer filters were selected on the basis of the layer sensitivity peaks of Kodachrome stock. The Wratten filters used are No. 29, No. 64 + No. 15, and No. 49. The top light in each color is adjusted by the appropriate rheostat so that tricolor printing of a black-and-white step-wedge is well duplicated on Kodachrome. Allowance has to be made for the current processing shifts in dye balance. The tricolor top light exposure is normally adjusted to be of the order of 60 mcs (meter candle seconds), while the lowest light averages about 6.5 mcs (Fig. 4).

It is essential that the normal or "center" light of a color printer be corrected by its color pack to duplicate an original gray scale test. Timing above or below the center light will shift the printed color balance away from "white" in accordance with the color temperature deviations which are produced. On the tricolor printer, this white-light balance is adjusted by the resistance presets to be provided whenever an equal number timing-light triplet is set up at the drop-board. For example, the nearest match to the gray scale test original

should be printed when the board is timed red 4, green 4 and blue 4, *i.e.*, the "center" light.

The three sets of seven timing lights are coded zero to six inclusive, with the center light triplet adjusted to duplicate closely a test gray density of 1.4. The seven coequal "white" combinations provide 30% of exposure change per step, each of which roughly corresponds

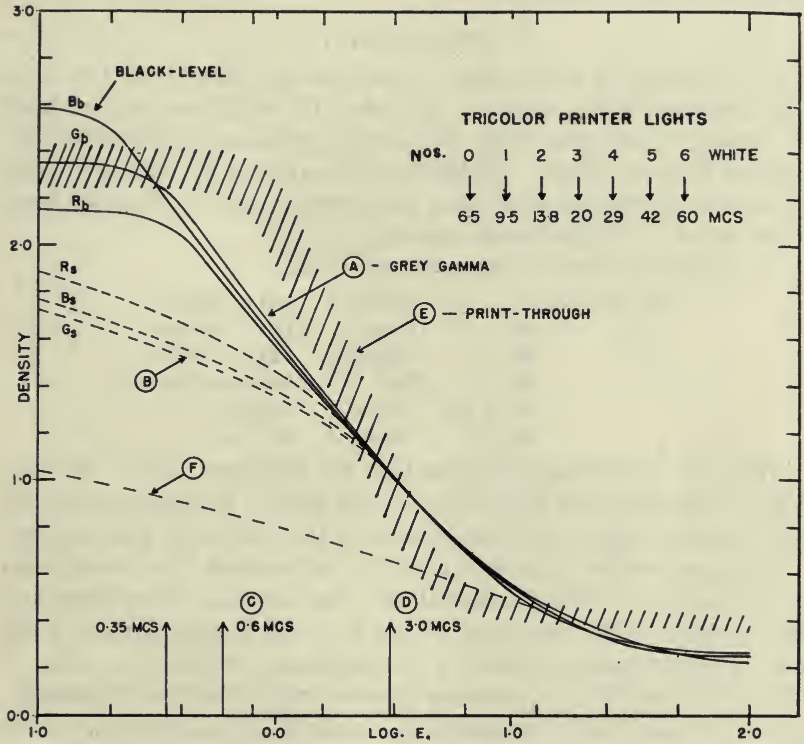

Fig. 4. Composite of relative gamma changes produced by "shadow-flashing." The printer exposures in terms of "white" timing lights are indicated relative to the resultant density of Kodachrome stock 5265.

to about three standard lights on a black-and-white printer. Single-color light changes on the tricolor printer give rise to relative hue shifts of approximately 10%. This has proved to be a satisfactory unit of change for average color-cast corrections.

All adjustments to the shadow-flasher unit are based on film density measurements. Small adjustments are effected through series resistors. The initial light output of 800-mcs exposure capacity is re-

duced by a pack of neutral density and color filters to about 0.6 mcs of equivalent cyan exposure. Less than 10% of the relative red exposure is transmitted. The green intensity is adjusted to provide about a 100% increase in green transmission over the unexposed film density value. The blue density is lowered by about 140% increase in transmission. The determining factors are discussed later under "Pre-Exposure Considerations."

Sensitometry

It was desirable to introduce a minimum of change from the existing black-and-white routine. A Kodak IIb Sensitometer, balanced to expose a good gray scale, was supplied with six additional sharp-cutting Wratten filters. All filters were corrected by neutral density to a common transmission value, and all exposures were compensated to be equal to the gray scale exposure.

The following Wratten filters are used:

Wratten No. 15	Yellow	530 to 700 mμ
64	Cyan	440 to 540 mμ
34	Magenta	440 and 680 mμ
29	Red	680 mμ at peak
64 + 15	Green	540 mμ
49	Blue	440 mμ

Relative transmission relationships are measured on the Western Electric densitometer fitted with tricolor filters. For convenience, all the hue exposures are plotted in terms of the equivalent gray gamma.

These color-scale exposures provided informative hue transmission relationships for timing information. For example, blue, green and red gammas, when examined at the step which is equivalent to 20 mcs of gray exposure, exhibited blue, green and red color densities of 3%, 7½% and 30% transmissions respectively. The lower chromaticity mid-tones, usually encountered in practice, tend to equalize such transmission differences. However, the familiar red build to flesh tone shadows is violently accentuated in a second generation print and the fault cannot be ignored.

An unexpected effect was disclosed in tricolor gammas of the cyan test (Fig. 5). The density to red was found to increase whenever the cyan exposure corresponded to an equivalent gray of 0.35 mcs or more. A cyan pre-exposure of this value was found largely to prevent a red gain in the corresponding steps of yellow gammas. Accordingly, the shadow-flasher pack is prepared on the basis of the cyan and yellow tests.

The wafer-probe light meter is used weekly to establish tricolor printer exposure values co-ordinated with the current processing drifts through the six color gamma tests. A silver-image loop of a resolution chart and a gamma strip is used to test the seven "white" printer-light timings.

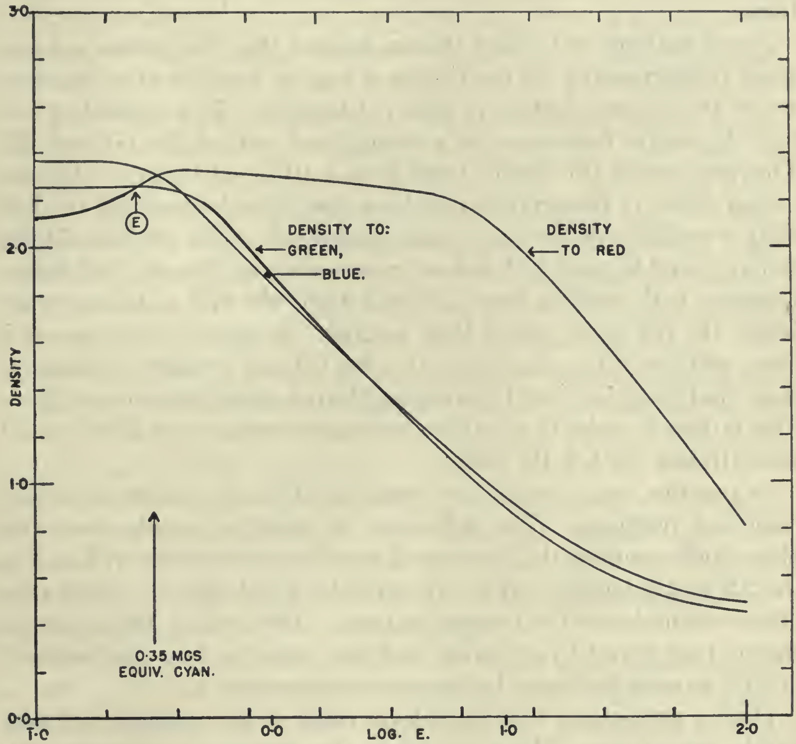

Fig. 5. Tricolor densities for a cyan sensitized gamma showing a virtual negative red exposure effect starting at E. No equivalent crossover appeared in characteristic curves for other hues.

Tricolor Timing

Balanced color originals which exhibit faulty exposures are given almost conventional black-and-white timing practice. For timing purposes, any horizontal equality of the tricolor printer timing numbers is regarded as a single printer light, for example, blue 3, green 3 and red 3 become "light three, white." However, white is not directly estimated. Tricolor timing depends upon the green exposure

which is estimated first. The red and the blue layer exposures are then estimated as two corrective "color tilts" given to the horizontal or white balance. In fact, the expression "color tilt" has come to denote the timing intent as distinguished from the original, visible color fault. The resultant complementary hue bias which may be generated in the printer is seldom directly considered in rapid timing operations.

As an example of tricolor timing, assume that the precise red and green proportions of the flesh tones of a given face are to be matched across two scenes which have been cut together. It is decided to correct the whiter face scene by a timing card code of B4, G4 and R5. This plus-one-R tilt should print with a 10% red boost in all compound colors in the original provided that layer latitude for the hue shift is available in the part-image considered. The untilted G4–B4 timing would be used with indoor scenes or strong blue sky highlights. Originals with medium blue skies will duplicate with a shift to cyan[1] which the red boost would tend to gray. In such a case, the color timer will also tilt up the blue with a B4, G3 and R4 light assignment. Note that this is effected by dropping the red–green slope by one light. This is done in order to avoid the feeling of overexposure which would result from a B5, G4, R5 timing.

In practice, color printing is complicated by the existence of dual color-cast problems. The differences in opacity to red, green and blue which comprise the black-level base densities, shown in Fig. 4 at the 2.2 to 2.6 density region, are variables which depend on the conditions occurring at the processing time. The density differences, as shown, may invert to any order and may range up to a displacement of 20% or more between the tricolor transmissions.

During projection, this black-level color of an original is of negligible importance. However, when the original is underexposed, normally mid-tone images tend to be shifted toward the 2.0 density region. These images partake of the hue of the current processing dye-balance, while images whose densities range around the 1.5 level may continue to exhibit the more noticeable color-cast effects of trilayer mismatch in the original shooting color temperature.

It will be apparent that whenever an underexposed sequence is "timed up" in printing, the prevailing process hue will modify the color of the restored mid-density images. At the same time, the original mid-tone color-cast, if any, will tend to be duplicated as an unrelated color-cast which may appear in the lighter tones. A nicety of

good judgment is required to achieve a satisfactory compromise in the tricolor corrections for a key film. It should be noted that such dual color-casts often present a greater problem when conventional black-and-white timing practices are used for release printing directly from the color original.

A misleading tricolor timing problem is presented when both an overexposure and a color-cast occur in the original. In this case, the color compensation selected to offset the color-cast of the middle densities may greatly modify the pastel shades of the lowest densities present. The lowered printing exposure which is indicated tends to duplicate the overexposed near-white areas as light grays* which may be noticeably tinted with the color of the offset used. When such a duplicate is screened, visual adaptation tends to cancel out the tint. Provided that the area in question is a large one such as the sky, then images of mid-densities on the screen will be affected by the same color adaptation. An illusional color-cast is thereby created which has the complementary tint to the printer offset employed. To counteract this illusion which is, of course, the same in hue as the color-cast in the original, it is necessary to raise the chromaticity of the color correction used until direct inspection shows a hint of it in mid-gray image-parts of the duplicate.

The presence of color-casts in the key film is fortunately not a major problem when release printing. Any reel-length over-all color-cast may be easily offset by an appropriate color-correcting filter. The key film dye-balance color requires no additional color pack changes provided the printing can be done on center light.

Owing to the low latitudes involved, the center light duplication of spectral densities of the order of 2.0 tend to print below the black-level. The shaded print-through gamma curve E shown in Fig. 4 indicates the average final latitude available. It will be appreciated that little opportunity exists for any timing exposure excursions unless some method of compression is introduced.

PRE-EXPOSURE CONSIDERATIONS (Shadow-Flashing)

The flashing of the raw stock by a white-light exposure of about 0.35 mcs will lower the tricolor gamma. As shown by curves A in Fig. 4, exposures below this level are not visibly recorded. The ad-

* See Fig. 4. A completely overexposed original with a transmission of the order of 60% (a density of 0.2) is reproduced by light No. 1 as a gray of only 20% (a density of 0.7).

dition of the above flash to each step not only shifts the point of shoulder inflection but it also produces a chromaticity limit to shadow details. In addition, any processing dye-balance color-cast tends to become more predictable—a useful feature when black-and-white timed duplicates are directly printed from the original. Flashed raw stock may be used for second generation duplications but the release film blacks should project as visually normal. Release film shadow-flashing is, therefore, definitely limited to the inflection point of the curve.

The differences between the relative gammas of the primary colors has been fully discussed in the JOURNAL.[1–3] They are the cause of the familiar red build-up which sometimes characterizes the shadow sides of faces. Various approaches to the problem, such as the intentional printing of a cyan color-cast or the use of a red light mask,[1] have been employed. However, shadow-flashing with cyan light proved a convenient control measure. The density to red at the black-level has been shown to increase when a cyan exposure is used (Fig. 5 at E). This process fault is most useful because of the concurrent reduction to the chromaticity of dark reds provided by the cyan transmission increase.

In practice, a higher shadow-flash than 0.35 mcs is needed for the key film stock. The compensation for a 2.25 red gamma which is the product of two generations of color printing would require a key film red gamma of approximately 0.45. Shadow-flashing with a predominantly cyan light (Fig. 4, C) of about 0.6 mcs is seen to produce a region of gamma of this order as manifested by the curves at B. The release printer light is adjusted to duplicate as neutral black the key film shadow-flash density levels R_s, B_s and G_s. The relatively greater density to red (R_s, to G_sB_s) of about 0.1 is required in order to compensate for the low cyan gamma of the final duplicate.

The existence of the shadow-flash "floor" permits the timer to concentrate on the maintenance of highlight details. Only shots possessing no near-whites require higher than a center-light exposure. The effect of shadow-flashing extends even to the mid-densities in counteracting possible dye-casts so that the hue substitutions of the original become the color timer's major consideration.

Precautions must be taken, however, not to make an automatic practice of undertiming because of the resolution losses which may be incurred. The resolution of details is not only a function of the grain size possessed by the silver images before bleaching; it is also de-

pendent upon the degree of density excursion forming the image details. For colored images, each increase in color density can be expected to exhibit lowered resolution. The density differences upon which picture details depend are thus reduced by lower timing. The following resolution figures give some idea of the definitions to be obtained when printing pure hues through a resolution chart two lights below normal:

			B	G	R		*lines/mm*
Black-and-white resolution on:	Center Light		4	4	4	→	55
	Red	"	0	0	2	→	17
	Green	"	0	2	0	→	25
	Blue	"	2	0	0	→	35

A gain of up to 15 lines/mm occurred when equivalent center-light pure hues printed the resolution charts. The reduction in maximum contrast due to flashing affected the practical color resolution by a loss of about 10 lines. In any event, the resolution losses from shadow-flashing do not begin to compare with the total loss of detail that occurs when portions of an image are cut off by printing below the gamma shoulder of non-shadow-flashed Kodachrome film.

Notes on Masking

While the various relative-brightness silver masks produce contrast reduction as outlined,[1] their routine use for one-light printing seems contraindicated. Such masks, either unsharp[4] or the more convenient sharp masks defocussed by double film base thicknesses, have printed uncommercial amounts of halo around those image fimbrillations which have extreme contrast.* Very lightly printed blue-sensitive masks for the reel-length equalization of skies show possibilities but timing complications ensue if full masking with tinted base panchromatic stock is used. For obvious reasons, negative masking cannot be used with overexposed scenes. Also the whole feasibility of masking is modified by the additional corrections which are required for the second generation duplicate.

A different proposition altogether is the use of color film for the masking of overexposed scenes. Wherever such scenes occur, it is desirable to accentuate the relative hues and contrasts. A conventional color print cannot be used as a mask, however, as normally ex-

* In this connection, it has been noted that, for masking registration purposes, neither the film direction nor the perforation sides are interchangeable.

posed images are always present in overexposed shots. For this reason, it is important to limit both the chromaticity and the gamma of the positive mask. This may be achieved by preflashing the masking stock. A white flash of approximately 3 mcs (see step D, Fig. 4) will set up a maximum minus density of about 10% transmission to all hues. The optimal value is not critical, nor is the time lapse between flashing and use, but the fogged stock should be pretested to ensure a neutral gray.

The overexposed original is printed onto this stock by center-light or lower. Provided that exact registration is used, the resulting pastel colored mask is an effective compensation means. The low mask gamma (about 0.35 γ, Fig. 4, curve E) largely avoids the problem of halos. Also the relative color and density shifts co-operate visually. The chroma-boosting is such that no exception to the routine timing and shadow-flash procedure is required. Full gamma Kodachrome masks used in conjunction with extreme printer-light tilts have provided endless combinations for special effects.

General Over-All Procedure

Expressed in printing vernacular, the production of a 16-mm key film intermediate follows this pattern:

The original is checked and very thin scenes are papered. Using the white fogged stock (3 mcs), the chroma-boosting masks are center-light printed between the papers.

After processing, the masks are frame synchronized with their originals by clear leader.

A first run-through is made over the (color) light box to judge the printer lights and the green exposure is set up on the timing card. Double timing from previous notches on the original is avoided by notching on the masking roll.

The color corrections are next estimated and the red and the blue timing tilts are entered on the timing card. Overexposed scenes are superimposed on their masks when viewed for timing.

The notched mask is then synchronized tail-out behind the original in the tricolor printer. Finally, the tricolor drop-board and the shadow-flasher are preset, the raw stock is threaded and the key film is printed.

Present Results

The major disadvantage to the practice of printing from key films lies in the resolution losses incurred at the 2.0 density region. A

limitation to the maximum chromaticity also occurs at the same region, but specific hue-shifts are considered to be less objectionable when the chromaticity is thus reduced.

Other observations on test prints made from key films have demonstrated:

A contrast of the same order as the original.

Improved maintenance of original shadow image densities.

Increased average transmission, jointly with improved reproduction of highlight areas.

Reduced color-shifts on a scene-to-scene basis, when compared with the original.

Reduced color-casts.

Reduced exposure changes.

Reduced effects from relative-brightness color-shifts.

Increased chromaticity and contrast from overexposed originals.

Increased chromaticity; reduced gray contrast for special effects.

In view of the opportunities for greater production control which are presented by the use of an intermediate stage, it is felt that the key film method can be the basis of improved release quality in 16-mm color.

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DISCUSSION

MR. WILLIAM OFFENHAUSER: I think this paper is a great contribution. I don't think at the moment that its import is fully appreciated, but we have for many years needed some analysis of second and later generation Kodachrome prints and some means to overcome their difficulties. There are a number of very fortunate things on the horizon. Now that the color control problem is reasonably well within view of solution, we have left the major problem of deterioration in resolving power; and from all that I have been able to hear, mostly through what we might call the underground, that solution, too, is in sight. So it may not be very many years before we will be able to accomplish the objective of having an original, storing it away for many years and yet being able to derive, let us say, third generation and further generation prints for use in the 16-mm fields. The goal is in sight.

Illuminating System and Light Control for 16-Mm Continuous Optical Printer

By WILLIAM BORNEMANN and WAYNE McKUSICK
Eastman Kodak Co., Rochester, N.Y.

Summary—**A continuous optical printer for producing highly corrected release prints at rapid printing speeds from 16-mm color originals is being developed and tested by the Eastman Kodak Co., Rochester, N.Y. All information on level and color balance of the printing light for each scene may be stored on the master film and the cuing device eliminates the necessity of notching the film. Also incorporated is a sprocket which automatically accommodates highly shrunk and damaged film inter-cut with fresh originals.**

The increasing demand for high-quality release prints from 16-mm color originals poses problems not readily solved by modifying existing printers. Since some original camera film may be included in the printing master from which the release prints are to be made, the requirements imposed on a color printer are indeed stringent.

First, release prints must be turned out at high speed; yet the extremely valuable original film must not be worn out until a profitable number of copies has been obtained. This requirement has been met in this experimental model by using precision gears to register the two sprockets of a continuous optical printer. Thus the film can be driven at high speed without the characteristic wear and damage of an intermittent film drive, or the abrasion of contact printing. The handling of the original film is further facilitated by an invaluable device which we call our "compensating sprocket." This is a sprocket which changes pitch continuously throughout the angle of film "wrap" and hence smoothly handles a wide range of shrinkages as well as worn or broken perforations.

Secondly, it has been found empirically that any change in exposure or color balance must be accomplished within one frame in order not to be objectionable when the print is projected. If, for example, the speed of the printer is set at 100 feet/min, then changes in color balance or exposure must be accomplished within 15 milliseconds; higher printing speeds obviously would require a proportionately faster action. Since the original film may vary

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widely in exposure and color balance because of the unavoidable conditions under which the shots are made, a *wide range* of correction is needed in each color in a release printer. But *small* corrective steps in each color are required in order that the continuity of color from scene to scene be accurately maintained. Thus, the total number of possible combinations of printing level and color corrections is staggering.

If one chooses values of optical density according to the geometrical progression 1, 2, 4, 8, 16, up to n and arranges to interpose any combination of these densities into a beam of light, then he has made available 2^n equal steps of light intensity. If then three beams of the same intensity, but each of a different primary hue, are so filtered and combined at the slit of the printer, a unit density may be chosen to give the desired fineness of color correction, and the value of n to give the necessary range.

In our experimental model, three condenser relay systems with the aid of multiple-layer selective reflectors combine three primary

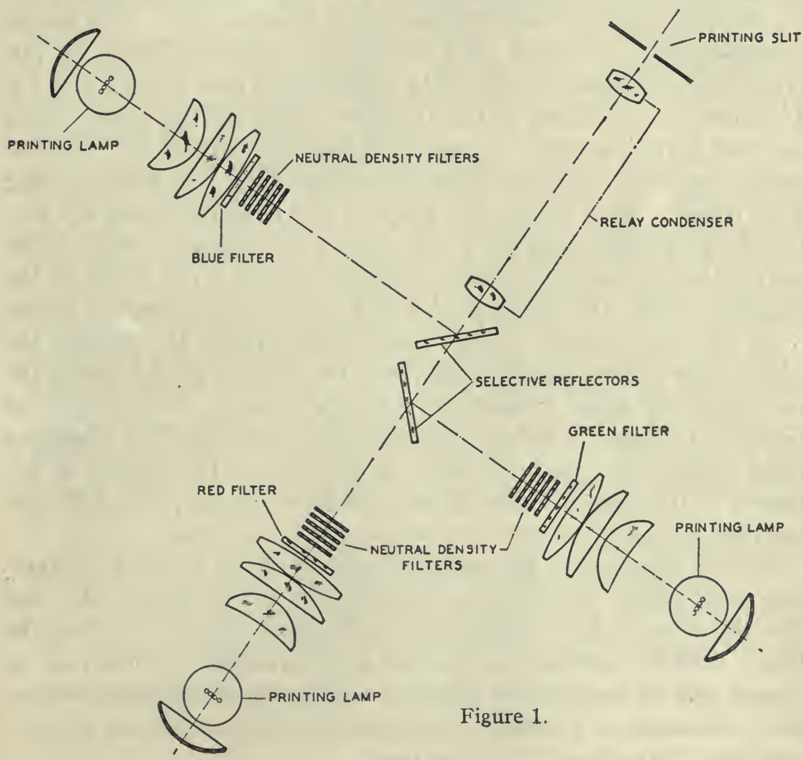

Figure 1.

beams, while solenoids move the corrective filters with the required speed (see Fig. 1). In order to use this range and speed of control, one must first assign to each scene of the original film a printing level specified in terms of the desired intensity of each of the three primary beams. This information must then be stored in such a way that it can reappear and alter the printing light at the beginning of each scene. Again selecting 100 feet/min for purposes of example, a one-foot scene would allow six-tenths of a second for "clearing the memory" and feeding in the prepared information of the following scene.

The memory system selected for storing the scene-by-scene printing information is a narrow track of magnetic material applied to the master film between the perforations and the edge of the film. If five filters are used in each of the three primary beams as described above, giving 32 steps in each color, then the conditions for printing any given scene may be specified by demanding that certain of the 15 filters (5 in each color) be interposed in their primary beams. Thus is established not only color balance but exposure as well. In a special viewer-recorder equipped with a magnetic recording head, we put down on the magnetic track at the beginning of each scene a series of 15 pulses corresponding to the 15 filters—each positive pulse calling for that particular filter to appear in its colored beam for the next scene, and each negative pulse specifying that the corresponding filter remain out of its beam. Positive and negative pulses are produced by opposite polarity on the coil of the recording head. Following this sequence of pulses, a triggering pulse is put down on the magnetic track, the function of which will become apparent below.

As the "color-timed" master film is run through the printer, the fifteen pulses pass a magnetic playback head on the printer before the corresponding scene reaches the printing "gate." This pattern of positive and negative pulses is electronically stored until the triggering pulse reaches the playback head, at which time the pattern is delivered to the solenoids that actuate the filters, accomplishing the entire light change within the first frame of the new scene.

By this approach to the problem not only is the printing information permanently stored as an integral part of the original film, but also the cuing of light changes is accomplished without notching the film. Both the printing information and the triggering pulse may be erased and re-recorded as desired, facilitating subsequent editing and refinement of printing conditions to give a maximum of color continuity throughout the release print.

New Brenkert Projection System For Drive-In Theaters

BY C. N. BATSEL

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AND H. J. BENHAM

BRENKERT LIGHT PROJECTION CO., DETROIT, MICH.

Summary—Some of the limitations and handicaps in illuminating large drive-in theater screens are discussed. The basic requirements for adequate screen lighting are reviewed and a newly developed arc light and projection system meeting those requirements are described.

THE POPULARITY OF THE DRIVE-IN THEATER started to accelerate during the war and soared to undreamed-of heights. Perhaps one reason for this rapid rise in popularity was that the drive-in theater gave people, who were in a war plant all day, a chance to relax and see a picture out in the open air and in a picnic-like atmosphere. Since the war, the popularity of the drive-in theater became even greater and, as a result, there is still a wild scramble to build drive-in theaters in all parts of the country.

Vast improvements have been made in the design of drive-in theaters compared to those built prior to the war: Buildings and grounds have been beautified; services such as ultra-modern snack bars and kiddies' playgrounds have been incorporated as added attractions; and parking areas have been increased in size so that many theaters will now accommodate over 1,000 cars. RCA pioneered in designing and building sound reproducing equipment especially for drive-in theaters so that good quality sound could be reproduced in every car through a neat and attractive in-car speaker. Producing a picture that can be clearly and easily seen by the occupants of all the cars in drive-in theaters, however, has always beeen a difficult task up to the present time.

There are a number of factors that contributed to the difficulty involved in high-quality projection for large drive-in theaters:

1. Long viewing distances between the cars in the rear ramps and the screen, in some cases over 850 ft. Detail of the picture, even

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though it may be 70 ft wide, is rapidly lost at these distances because visibility is lessened and the elements also interfere and cut down on detail.

2. Long projection throws of 300 ft or more. Here again interference of dust, mist, fog and rain have a deleterious effect on picture quality.

3. Extremely large picture areas, some over 3,000 sq ft. It is extremely difficult to provide adequate illumination over picture areas of this size so that the people in cars in the rear and on the sides of the parking area can see details.

4. Wide viewing angles, particularly at the ends of the front ramps. This is a limitation only for those cars at the extreme sides and reasonably close up front, and is a limitation that cannot be remedied except by changing the shape of the parking area with a considerable loss in productive area.

5. Moonlight and other interferences such as electric signs, highway lights and street light.

The net result of these limitations is that most drive-in theaters have pictures that are considerably inferior to those in regular indoor theaters. It is also quite apparent from the nature of these limitations that by providing a sufficient amount of projected light the quality of the drive-in theater picture could be considerably enhanced. Very little work has been done in establishing the lighting values for outdoor screens; consequently, there are no standards such as we have for indoor screens. It is generally conceded that for the same viewing distances, large screens do not need so much illumination as smaller screens to permit the viewer to see an equivalent amount of detail. Recent observations and measurements of present screen illumination in outdoor theaters indicate that a 50% to 100% increase from present levels is necessary if the picture quality is to be materially increased. Such an increase in illumination will bring the light on large screens up to 6 ft-c at the center; this will provide reasonably satisfactory quality of projection under all but the most extreme conditions. A field flatness of at least 70% is desirable, but reasonably good picture quality can be had with a field flatness as low as 60%. Lighting values such as these can be obtained on screens 35 to 40 ft in width using standard projector mechanisms and suprex-type arc lamps.

A super high-intensity arc lamp, burning 13.6-mm high-intensity positive carbons at 150 amp operated in combination with a projector

equipped with double disc-type shutters and using $f/2.0$ condensers and projection lenses, will deliver approximately 7.6 ft-c at the center of a screen 40-ft wide, with an 80% light distribution.[1] This same projection system will deliver approximately 3.5 ft-c at the center of a 60-ft screen with the same light distribution. Increasing this light intensity beyond these values is not very practical mainly due to heat problems that arise and the probable damage to film, unless some adequate means of cooling is provided.

Heat-absorbing glass is sometimes used to reduce the heat on the film, but all known glass heat filters absorb a considerable amount of the visible light rays as well as change the color of the projected light. The net result is a visible loss of considerably more than that indicated by a photometer with a Viscor filter. Light measurements made using arc lamps operated at 170 amp with heat filters actually give screen results which are inferior to those when using the same arc lamp operated at 150 amp without the heat filter. Other methods of cooling, such as by water-cooled apertures, do not provide adequate protection to the film.

The light projection problem therefore resolved itself into the following objectives:

1. Obtaining a carbon capable of producing approximately 26,000 lumens on the screen without the projector running when operated at its rated current so as to obtain at least 6 ft-c at the center of a 60-ft screen.

2. Designing an arc lamp capable of operating satisfactorily using high-current carbons of this type, yet flexible enough so that it will perform equally well when operated at lower currents.

3. Designing a new film trap and gate assembly with associated cooling system permitting transmission of maximum light from the arc lamp to the screen.

All of these objectives have been met with the introduction of new projection and arc lamp equipment known as the Brenkert Supertensity system and developed by the Brenkert Light Projection Company. Incorporated in this system are methods for adequate cooling of the arc lamp, projector and film so that this system can be operated with high amperage carbons at the full current rating of the carbon and without damage to the film or the equipment. Using this system with the 13.6-mm super high-intensity carbon it was possible to use the maximum amount of light developed when these carbons were operated at their maximum rating of 170 amp without employ-

Fig. 1. Supertensity Lamp.

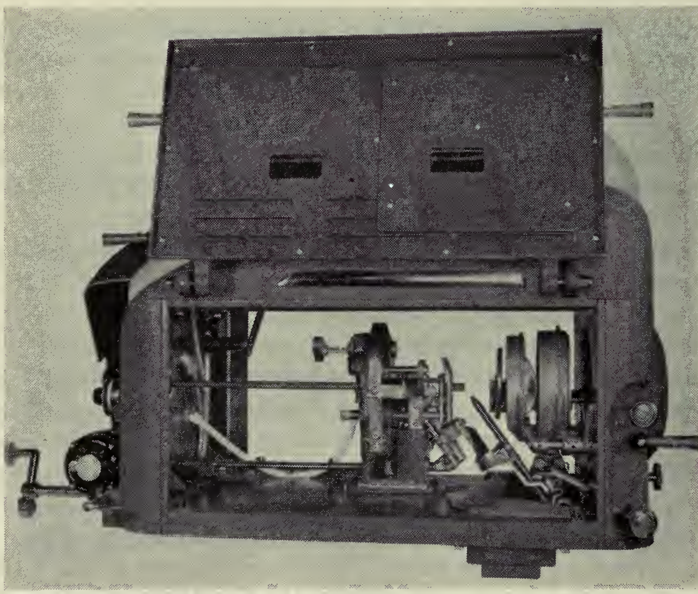


Fig. 2. Interior of Supertensity Lamp; showing positions of lenses, carbon feeds, mechanisms and air outlets.

ing light-wasting and color-changing glass heat filters. This was more light than was ever used before without glass heat filters to prevent film damage.

With this new Brenkert Supertensity system, however, even more light could be used, without damaging film, than could be developed by the 170-amp 13.6-mm super high-intensity carbon. The new 13.6-mm "Hitex" Super carbon recently announced by the National Carbon Division offers such a possibility of increased light. This carbon is rated at 170 to 180 amp; the trim is complete, using a ½-in. heavy-duty Orotip negative. When operated at 180 amp in the Supertensity system approximately 7 ft-c can be projected on the center of a 60-ft screen with approximately 70% screen distribution. The light produced when operating this new "Hitex" carbon at 180 amp is much whiter than that produced by the Supertensity system and standard super high-intensity carbon when operated at 170 amp, so that to the eye the light on the screen appears greater than indicated by a photometer.

The Arc Lamp

In designing the lamp house consideration was given to such things as ease of operation, cooling, placement of the carbon feed mechanism and appearance. The housing is extremely large by comparison to other arc lamps, having a content of approximately 10 cu ft, which aids in cooling and at the same time greatly facilitates operation, servicing and cleaning.

The walls of the housing are hollow, with intake ventilation vents around the bottom through which air enters, passes up through the walls and exhausts through vents located around the stack port at the top. Forced ventilation is supplied to the interior of the lamp by a fan which is driven by the carbon feed motor. Air from this source is passed through ducts which are part of the base casting and terminate under the positive feed, the carbon feed and the negative carbon holder. The entire lamp house is constructed of solid aluminum castings, completely lined and ventilated to prevent its becoming excessively hot and warping out of shape. This is especially important to permit an accurate arc image to be projected on the arc-image screen.

The positive carbon feed mechanism uses a three-roller head which, while rotating the carbon, feeds it toward the arc; grease-packed ball bearings are used throughout. Many new and very desirable features are incorporated in the design of this new positive carbon feed

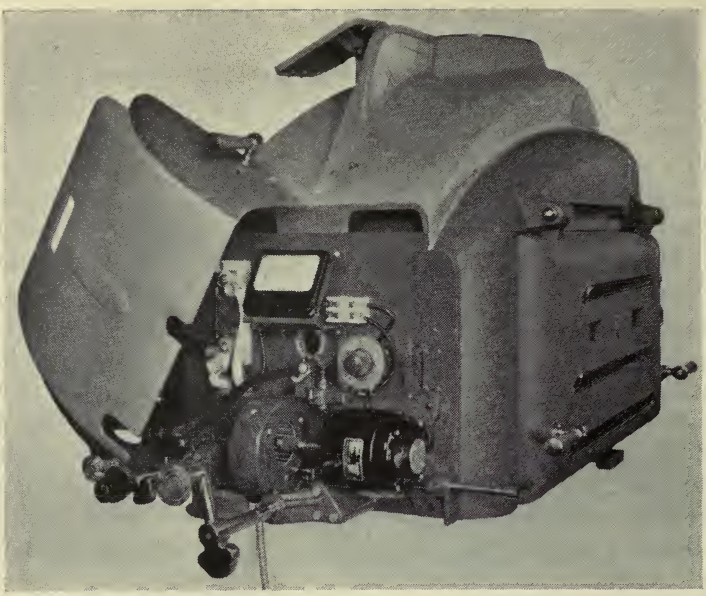


Fig. 3. Rear view of Supertensity Lamp; showing arc current meter, hand carbon feeds and motor feed mechanism.

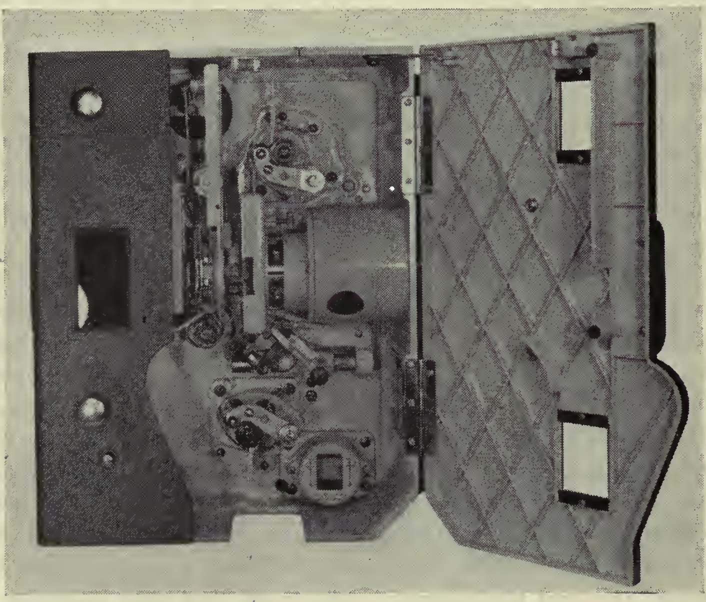


Fig. 4. View of BX-80 Projector; showing air jet position.

mechanism. The three-feed rollers are ¾ in. in length and the full length of each roller contacts the carbon at points equidistant on the circumference of the carbon with a pressure of approximately 50 lb existing between the rollers and the carbon. Thus, positive feeding of the carbon is assured at all times; tests at the factory have proved that it is impossible to stall the carbon while the feed mechanism is in operation. Accurate alignment of the carbon is assured regardless of the length of trim because of the three-suspension method of holding the carbon and because of the proximity of the rollers to the arc. The positive carbon brushes are located directly in front of the feed rollers. The carbon passes through a high heat baffle to the crater point. This baffle protects the mechanism and serves as an air guide to prevent the forced air ventilation from disturbing the arc. The linear dimensions of the feed mechanism brushes and baffle are short, permitting the carbon to be burned to a stub of approximately 3½ in. Current feeds to the carbons are symmetrically arranged to assure perfect magnetic balance regardless of operating current values and without the use of auxiliary permanent magnets. This results in a white and unwavering light on the screen at all operating current values.

The negative carbon feed is placed alongside the positive feed. An L-shaped arm supports the negative carbon clamp. This construction keeps all gears and moving parts away from the intense heat of the light beam, reducing heat deterioration of the parts considerably. The forced air cooling makes it possible to eliminate the necessity of using graphite lubricant; ordinary motor oil is used throughout the lamp for lubrication.

The carbon feed motor, the ventilating fan and all controls are placed at the rear of the lamp with the hand-feed cranks extending through the cover. The arc current meter is also visible through the cover, permitting easy reading of the arc current at all times. The carbon positions are indicated on the large ground glass screen which is located on top of the lamp, and can easily be seen at all times from any position in the booth.

Manual striking of the arc is accomplished by operating a lever located at the right rear of the lamp. This operation raises the negative to contact the positive and then allows it to fall back quickly into operating position when the lever is released. Using this type of arc striker, the arc can be struck at full rated operating current without danger of damaging or cracking the arc crater.

The lamp is equipped with high-speed $f/2.0$ condensers. The condenser next to the arc is fused quartz; the front one is Pyrex. This complete lens assembly is adjustable laterally, vertically and forward and backward so that it can be properly positioned to obtain maximum screen brightness and uniform distribution. The condensers are protected during striking by a hand-operated dowser. This type of condenser system is recommended wherever maximum light on the screen is the prime factor. The standard, less expensive Brenkert condensers can also be used in this lamp for indoor theater use where flatness of field is the prime factor and high efficiency light transmission is not so important.

THE PROJECTOR

Safely transmitting the unrestricted light from the arc lamp through the projector and film necessitated some revolutionary changes in design of the film side of the projector. In addition to protecting the film from heat damage, the parts of the projector exposed to the intense heat in the light beam had to be constructed of very high heat-resisting materials and had to be adequately cooled. The projector selected for this modification was the Brenkert De-Luxe BX-80. In addition to its inherent rugged construction, the BX-80 is equipped with double rear disc-type shutters. This type of shutter construction has the advantage of passing more light with less heat on the film than a projector mechanism using front and rear disc-type shutters or barrel-type shutters.

The film trap and gate assembly is designed and constructed to cope with the heat problem by making use of high-heat-resistant reflector baffles at the point of light entry to the film trap assembly. Fire shutters are constructed of metal which is highly heat resistant.

Cooling of the film and gate assembly is accomplished by using compressed air. The effectiveness of this type of cooling is dependent on several factors such as air pressure, velocity and the manner in which the air is directed onto the film. The entire film trap assembly is also effectively cooled by this air. Water-cooling the metal parts of the film trap around the aperture was tried but was discarded as unsatisfactory.

The maximum heat in the light beam at the aperture is on the emulsion side of the film. This heat, which is energy absorbed, is proportional to the density of the image on the film. It is also somewhat

greater at the center of the aperture than at the sides. Distribution of the air stream must, therefore, be such that sufficient air contacts all parts of the film so as to absorb the heat and carry it away. The metal parts of the film trap and gate are automatically cooled by the air as it is exhausted from around the film trap assembly.

The proper application and distribution of the air stream is obtained by specially designed jets. They are placed front and rear of the film and positioned so that air is ejected horizontally against the film. The jets are on the side of the gate next to the center plate of the projector and the air is blown toward the operating side of the mechanism.

The volume of air directed against the emulsion side of the film is somewhat greater than against the front or base side of the film. Flutter and consequent focus trouble are completely eliminated by proper construction and placement of these jet nozzles.[2] The angle at which the air strikes the film is also important in this respect.

Air is piped to the projectors from a pump which is usually installed in the motor generator room. One reason for using an air pump is to supply air completely free of oil, something which cannot always be done with a regular piston-type compressor. A silencer and cleaner are attached to the air pump to reduce the noise and dust in the air.

A number of these installations have been made in several parts of the United States, many of them more than one year ago. The picture quality at the drive-in theaters using this system is far superior to anything ever seen before in a drive-in theater.

Lighting standards which were mentioned previously in this paper are not intended to be optimum, but it has been proven that, if the larger drive-in theaters would bring their screen illumination up to these values, a very desirable improvement in projection could be obtained.

REFERENCES

(1) *National Projector Carbons*, 4th Ed., National Carbon Div., Cleveland, Ohio, 1949.

(2) F. J. Kolb, Jr., "Air cooling of motion picture film for higher screen illumination," *Jour. SMPE*, vol. 53, pp. 635–664; December, 1949.

Note on Metol Analysis In Photographic Developers

By MARTIN IDELSON

Technical Dept., Pavelle Color Inc., New York, N.Y.

The method of Brunner, Means and Zappert[1] for the determination of metol in Ansco Color Positive first developer, A-502, was found by us to give a titration curve with no true inflection point. Instead, there was a region of about 0.5 ml in which the inflection might occur; therefore, the error in the determination may be quite large. By substituting acetic acid for water as solvent for the titration, and 0.1 *N* sulfuric or perchloric acid in acetic acid for the conventional 0.1 *N* hydrochloric acid, a better inflection point may be obtained. No changes except those already mentioned were made in the procedure given by Brunner, Means and Zappert.

Briefly, the theory is that whether a substance is an acid or base depends on the solvent in which it is dissolved.[2,3] Nitric acid is commonly regarded as a strong acid, but when nitric acid is dissolved in concentrated sulfuric acid it acts as a moderately strong base.

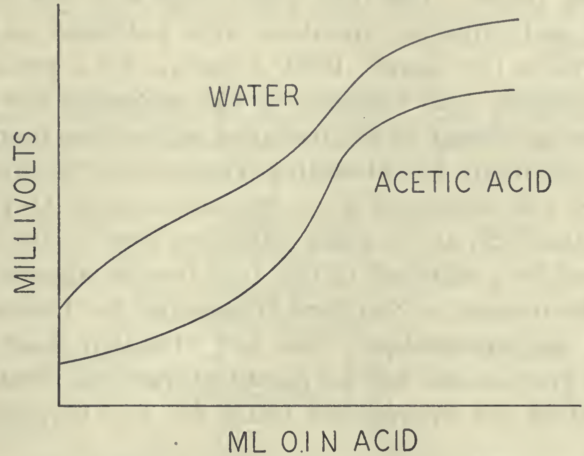
Metol is an amino phenol. In water the amino group is a weak base and the phenol group is a very weak acid. The net effect is a weakly basic reaction towards acids. If, however, acetic acid is used as the solvent, the acidity of the phenol group is completely masked while the basicity of the amino group is enhanced.

The titrant must be a stronger acid than acetic acid; sulfuric and perchloric acids are very convenient and a 0.1 *N* solution of either in glacial acetic can be accurately standardized against diphenylguanidine potentiometrically or with methyl violet indicator.

A comparison of two titrations, one in water and the other in acetic acid, is shown in the accompanying graph. On calculating the change in emf per milliliter at the equivalence point, it was found that for water the ratio was 64 mv per ml and for acetic acid, the ratio was 112 mv per ml. Furthermore, these values applied over a region of 0.5 and 0.2 ml respectively. It can be seen that the end point can be found more closely with acetic acid as solvent.

A Contribution: Submitted December 28, 1949.

It should be noted that a precipitate forms when the titration with ceric sulfate is performed. The end point is not as sharp as in water, and either a separate sample should be prepared or an aliquot part of the combined extracts of metol and hydroquinone may be used.



Comparison of typical titration curves from a metol-water sulution and a metol-acetic acid solution.

REFERENCES

(1) A. H. Brunner, Jr., P. B. Means, Jr., and R. H. Zappert, "Analysis of developers and bleach for Ansco Color Film," *Jour. SMPE*, vol. 53, pp. 25–35; July, 1949.

(2) L. P. Hammett, *Physical Organic Chemistry*, Chap. II, McGraw-Hill, New York, 1940.

(3) N. F. Hall and J. B. Conant, "A study of superacid solutions: I," *J. Amer. Chem. Soc.*, vol. 49, p. 3047; 1927.

New American Standards

Six new American standards, approved by the American Standards Association on March 14, 1950, appear on the following pages. The four which deal with 16- and 8-mm camera and projector apertures were published as proposed standards in the March, 1949, Journal, for a period of trial and comment. No criticism of the proposals was received; therefore no change in the technical content has been made.

The Standard for Mounting Frames for Theater Screens (Z22.78) was developed by a Subcommittee of ASA Sectional Committee Z22, and is being published here for the first time. The need for a standard of this type became apparent in 1946 when the revision of Standard Dimensions for Theater Screens Z22.29 was undertaken. The new standard describes good current practice and will aid manufacturers and theater owners in selecting the appropriate frame for any particular application.

The Standard for 16-Mm Sound Projector Test Film (Z22.79) is also being published for the first time. It was developed by the joint Test Film Committee of the Motion Picture Research Council and the Society as a revision of War Standard Z52.2. It describes a 16-mm version of the 35-Mm Theater Sound Test Film, familiar to many members as the old "Academy" test reel. The primary difference between this American Standard and the old War Standard is of an editorial nature. The detailed procedure for selecting appropriate sound test samples is now covered in the American Standard for the 35-Mm Film Z22.60 which was approved in 1948 and was published in the November, 1948, Journal.

One other important change concerns the re-recording characteristic to be used in making up the 16-mm film. During the war there was no agreement as to what high-frequency equalization should be used in the 16-mm re-recording channel. Now, however, the major studios have reached an agreement, and the recommendations have been published as the Research Council Bulletin N-1.1.

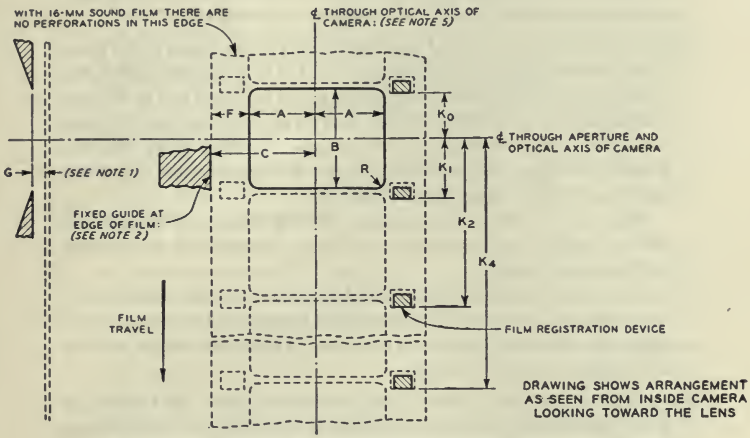
American Standard

Location and Size of Picture Aperture of 16-Millimeter Motion Picture Cameras

ASA
Reg. U. S. Pat. Off.
Z22.7-1950
Revision of
Z22.7-1941
and
Z22.13-1941
*UDC 778.53

Page 1 of 3 pages

This standard applies to both silent and sound 16-mm. motion picture cameras. It covers the size and shape of the picture aperture and the relative positions of the aperture, the optical axis, the edge guide, and the film registration device. The notes are a part of this standard.



Dimension	Inches	Millimeters	Note
A (measured perpendicular to edge of film)	0.201 minimum	5.11 minimum	1
B (measured parallel to edge of film)	$0.292 {+0.006 \atop -0.002}$	$7.42 {+0.18 \atop -0.05}$	1
C	0.314 ± 0.002	7.98 ± 0.05	2
F	0.110 minimum	2.79 minimum	3
K_0	0.125 ± 0.002	3.18 ± 0.05	4
K_1	0.175 ± 0.002	4.44 ± 0.05	4
K_2	0.474 ± 0.002	12.04 ± 0.05	4
K_3	0.773 ± 0.002	19.63 ± 0.05	4
K_4	1.072 ± 0.001	27.23 ± 0.03	4
R	0.020 maximum	0.51 maximum	1

Approved March 14, 1950 by the American Standards Association Incorporated
Sponsor: Society of Motion Picture and Television Engineers Incorporated

*Universal Decimal Classification

American Standard

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ASA Reg. U. S. Pat. Off.
Z22.7-1950
Revision of Z22.7-1941 and Z22.13-1941
*UDC 778.53

The angle between the vertical edges of the aperture and the edges of normally positioned film shall be 0 degrees, ± ½ degree.

The angle between the horizontal edges of the aperture and the edges of normally positioned film shall be 90 degrees, ± ½ degree.

Note 1: Dimensions A, B, and R apply to the size of the image at the plane of the emulsion; the actual picture aperture has to be slightly smaller. The exact amount of this difference depends on the lens used and on the separation (dimension G) of the emulsion and the physical aperture. G should be no larger than is necessary to preclude scratching of the film. The greatest difference between the image size and aperture size occurs with short focal-length, large diameter lenses.

Dimensions A and B are consistent with the size of the images on a 16-mm. reduction print made from a 35-mm. negative with the standard 2.15 reduction ratio.

It is desirable to hold the vertical height of the actual aperture to a value that will insure a real (unexposed) frameline. This results in less distraction when the frameline is projected on the screen than is the case when adjacent frames overlap.

Note 2: The edge guide is shown on the sound-track edge. This location for it has the advantage that the rails bearing on the face of the film along this edge and also between the sound track and picture area can be of adequate width. Disadvantages of this location for the edge guide are that, because film shrinkage and tolerances affect the lateral position of the perforations, the pulldown tooth must be comparatively narrow and will not always be centered in the perforation.

The guide can be on the other edge, adjacent to the perforated edge of sound film. With the guide at this edge, the width of the pulldown tooth does not have to be decreased to allow for shrinkage. However, because of variations introduced by shrinkage of film, this location for the edge guide has the important disadvantage that it makes extremely difficult the provision of rails of adequate width to support the sound-track edge without encroaching on, and consequently scratching, the picture or sound-track area. (See Section 3, Proposals for 16-mm. and 8-mm. Sprocket Standards, Vol. 48, No. 6, June 1947, Journal of the Society of Motion Picture Engineers).

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The film may be pressed against the fixed edge guide by a spring, by the tendency of the film to tilt in the gate, or by other means. In the second case, there is a fixed guide for each edge of the film. The important point is to have the film centered laterally on the optical axis.

Dimension C is made slightly less than half the width of unshrunk film so that the film will be laterally centered if it has a slight shrinkage at the time it is run in the camera. This is the normal condition. As indicated by the above discussion, C may be measured in either direction from the vertical centerline.

Note 3: Dimension F must be maintained only when a photographic sound record is to be made on the film that passes through the camera; otherwise F may be disregarded.

Note 4: The K dimensions are measured along the path of the film from the horizontal centerline of the aperture to the stopping position of the registration device. Both the dimensions and tolerances were computed to keep the frameline within 0.002 to 0.005 inch of the centered position for films having shrinkages of 0.0 to 0.5 per cent at the time they are exposed in the camera. For any given camera, use the value of K corresponding to the location of the registration device.

If the film does not stop exactly where the film registration device leaves it, because of coasting or some other cause, a slight adjustment of the value of K will be necessary. This will be indicated if film that has a shrinkage of 0.2 to 0.3 per cent when it is run in the camera does not show a properly centered frameline. From such a test, the amount and direction of the adjustment can be determined.

Note 5: "Optical axis of camera" is defined as the mechanical axis or centerline of the sleeve or other device for holding the picture-taking lens. Except for manufacturing tolerances, it coincides with the optical axis of the lens.

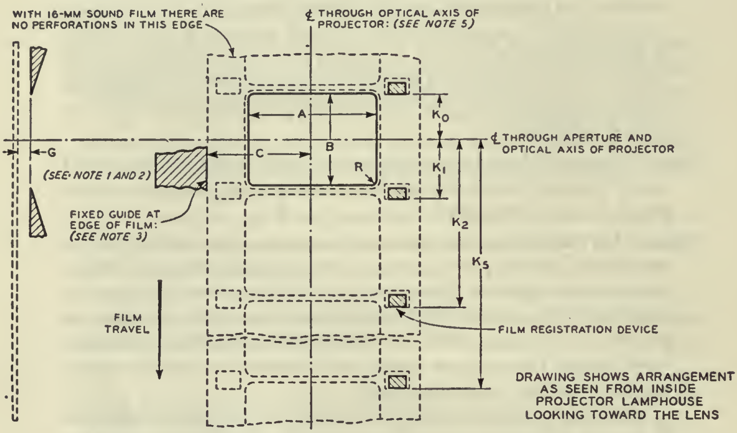
American Standard

Location and Size of Picture Aperture of 16-Millimeter Motion Picture Projectors

ASA Reg. U. S. Pat. Off.
Z22.8-1950
Revision of Z22.8-1941 and Z22.14-1941
*UDC 778.55

Page 1 of 3 pages

This standard applies to both silent and sound 16-mm. motion picture projectors. It covers the size and shape of the picture aperture and the relative positions of the aperture, the optical axis, the edge guide, and the film registration device. The notes are a part of this standard.



Dimension	Inches	Millimeters	Note
A (measured perpendicular to edge of film)	0.380 ± 0.002	9.65 ± 0.05	1
B (measured parallel to edge of film)	0.284 ± 0.002	7.21 ± 0.05	1
C	0.314 ± 0.002	7.98 ± 0.05	3
K_0	0.124 ± 0.005	3.15 ± 0.13	4
K_1	0.174 ± 0.005	4.42 ± 0.13	4
K_2	0.473 ± 0.005	12.01 ± 0.13	4
K_3	0.771 ± 0.005	19.58 ± 0.13	4
K_4	1.070 ± 0.005	27.18 ± 0.13	4
K_5	1.368 ± 0.005	34.75 ± 0.13	4
R	0.020 maximum	0.51 maximum	1

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The angle between the vertical edges of the aperture and the edges of normally positioned film shall be 0 degrees, ± ½ degree.

The angle between the horizontal edges of the aperture and the edges of normally positioned film shall be 90 degrees, ± ½ degree.

Note 1: Dimensions A, B, and R apply to the portion of the image on the film that is to be projected; the actual opening in the aperture plate has to be slightly smaller. The exact amount of this difference depends on the lens used and on the separation (dimension G) of the emulsion and the physical aperture. To minimize the difference in size and make the image of the aperture as sharp as practicable on the screen, G should be no larger than is necessary to preclude scratching of the film. When the reduction in size from the image to the actual aperture is being computed, it is suggested a 2-inch f/1.6 lens be assumed unless there is reason for doing otherwise.

Note 2: The limiting aperture is shown as being between the film and the light source so that it will give the maximum protection from heat. If other factors are more important, it may be on the other side of the film.

Note 3: The edge guide is shown on the sound-track edge. This location for it has the advantage that the rails bearing on the face of the film along this edge and also between the sound track and picture area can be of adequate width. Disadvantages of this location for the edge guide are that, because film shrinkage and tolerances affect the lateral position of the perforations, the pulldown tooth must be comparatively narrow and will not always be centered in the perforation. Also, in some prints the sound-track edge is slit after processing, in which case there is likely to be some lateral weave between this edge and the pictures.

The guide can be on the other edge, adjacent to the perforated edge of sound film. With the guide at this edge, the width of the pulldown tooth does not have to be decreased to allow for shrinkage. Also, slitting the sound-track edge after processing will not introduce lateral unsteadiness. However, because of variations introduced by shrinkage of film, this location for the edge guide has the important disadvantage that it makes extremely difficult the provision of rails of adequate width to support the

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sound-track edge without encroaching on, and consequently scratching, the picture or sound-track area. (See Section 3, Proposals for 16-mm. and 8-mm. Sproket Standards, Vol. 48, No. 6, June 1947, Journal of the Society of Motion Picture Engineers).

The film may be pressed against the fixed edge guide by a spring, by the tendency of the film to tilt in the gate, or by other means. In the second case, there is a fixed guide for each edge of the film. The important point is to have the film centered laterally on the optical axis.

Dimension C is made slightly less than half the width of unshrunk film so that the film will be laterally centered if it has a slight shrinkage at the time it is run in the projector. This is the normal condition. As indicated by the above discussion, C may be measured in either direction from the vertical centerline.

Note 4: The K dimensions are measured along the path of the film from the horizontal centerline of the aperture to the stopping position of the registration device. It is customary to provide a framing movement of 0.025 inch above and below this nominal position. For any given projector, use the value of K corresponding to the location of the registration device.

If the film does not stop exactly where the film registration device leaves it, because of coasting or some other cause, a slight adjustment of the value of K will be necessary.

Note 5: "Optical axis of projector" is defined as the mechanical axis or centerline of the sleeve for holding the projection lens. Except for manufacturing tolerances it coincides with the lens axis.

American Standard

Location and Size of Picture Aperture of 8-Millimeter Motion Picture Cameras

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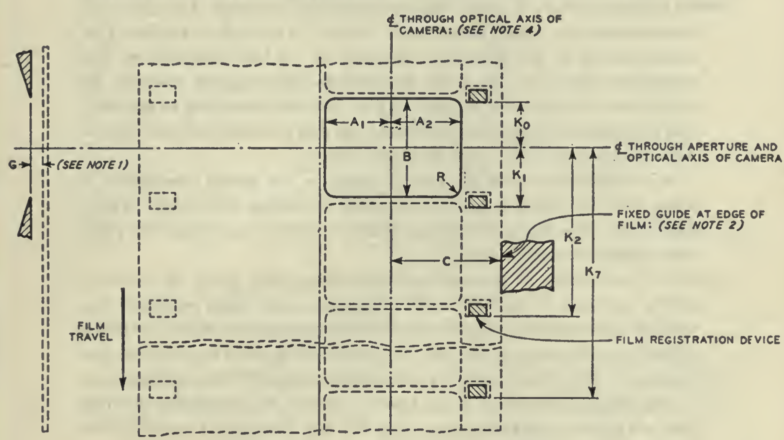
Reg. U. S. Pat. Off.
Z22.19-1950
Revision of
Z22.19-1941
*UDC 778.53

This standard applies to 8-mm. motion picture cameras. It covers the size and shape of the picture aperture and the relative positions of the aperture, the optical axis, the edge guide, and the film registration device. The notes are a part of this standard.



DRAWING SHOWS ARRANGEMENT AS SEEN FROM INSIDE CAMERA LOOKING TOWARD THE LENS

Dimension	Inches	Millimeters	Note
A_1 (measured perpendicular to edge of film)	0.094 min., 0.104 max.	2.39 min., 2.64 max.	1
A_2	0.094 min.	2.39 min.	1
B (measured parallel to edge of film)	$0.138 \begin{smallmatrix} +0.008 \\ -0.001 \end{smallmatrix}$	$3.51 \begin{smallmatrix} +0.20 \\ -0.03 \end{smallmatrix}$	1
C	0.205 ± 0.002	5.21 ± 0.05	2
K_0	0.050 ± 0.002	1.27 ± 0.05	3
K_1	0.100 ± 0.002	2.54 ± 0.05	3
K_2	0.249 ± 0.002	6.32 ± 0.05	3
K_3	0.399 ± 0.002	10.13 ± 0.05	3
K_4	0.549 ± 0.002	13.94 ± 0.05	3
K_5	0.698 ± 0.002	17.73 ± 0.05	3
K_6	0.848 ± 0.002	21.54 ± 0.05	3
K_7	0.998 ± 0.002	25.35 ± 0.05	3
R	0.010 maximum	0.25 maximum	1

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Note 1: Dimensions A, B, and R apply to the size of the image at the plane of the emulsion; the actual picture aperture has to be slightly smaller. The exact amount of this difference depends on the lens used and on the separation (dimension G) of the emulsion and the physical aperture. G should be no larger than is necessary to preclude scratching of the film. The greatest difference between the image size and aperture size occurs with short focal-length, large diameter lenses.

It is desirable to hold the vertical height of the actual aperture to a value that will insure a real (unexposed) frameline. This results in less distraction when the frameline is projected on the screen than is the case when adjacent frames overlap.

Note 2: The film may be pressed against the fixed edge guide by a spring, by the tendency of the film to tilt in the gate, or by other means. In the second case (generally used in pre-loaded magazines), there is a fixed guide for each edge of the film. The important point is to have the film located in the correct lateral position with respect to the optical axis.

The value of dimension C has been chosen on the assumption that the film will have a slight shrinkage when it is run through the camera. This is the normal condition.

Note 3: The K dimensions are measured along the path of the film from the horizontal centerline of the aperture to the effective stopping position of the registration device. Both the dimensions and tolerances were computed to keep the frameline within 0.002 to 0.005 inch of the centered position for films having shrinkages between 0.0 and 0.5 per cent at the time they are exposed in the camera. For any given camera, use the value of K corresponding to the location of the registering device.

If the film does not stop exactly where the film registration device leaves it, because of coasting or some other cause, a slight adjustment of the value of K will be necessary. This will be indicated if film that has a shrinkage of 0.2 to 0.3 per cent when it is run in the camera does not show a properly centered frameline. From such a test, the amount and direction of the adjustment can be determined.

Note 4: "Optical axis of camera" is defined as the mechanical axis or centerline of the sleeve or other device for holding the picture-taking lens. Except for manufacturing tolerances, it coincides with the optical axis of the lens.

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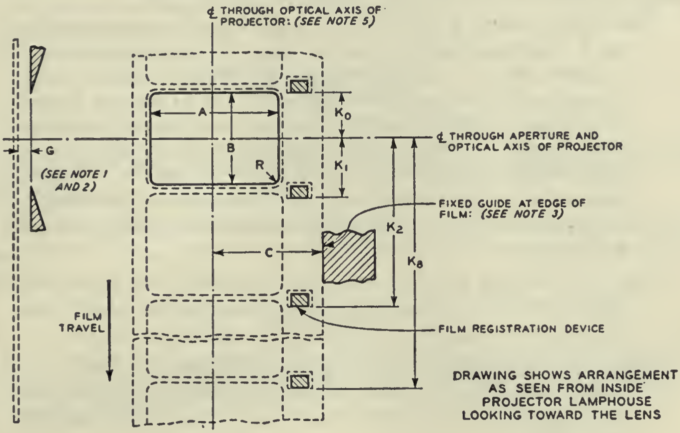
*UDC 778.55

This standard applies to 8-mm. motion picture projectors. It covers the size and shape of the picture aperture and the relative positions of the aperture, the optical axis, the edge guide, and the film registration device. The notes are a part of this standard.



Dimension	Inches	Millimeters	Note
A (measured perpendicular to edge of film)	0.172 ± 0.001	4.37 ± 0.03	
B (measured parallel to edge of film)	0.129 ± 0.001	3.28 ± 0.03	1
C	0.205 ± 0.002	5.21 ± 0.05	3
K_0	0.050 ± 0.005	1.27 ± 0.13	4
K_1	0.100 ± 0.005	2.54 ± 0.13	4
K_2	0.249 ± 0.005	6.32 ± 0.13	4
K_3	0.398 ± 0.005	10.11 ± 0.13	4
K_4	0.547 ± 0.005	13.89 ± 0.13	4
K_5	0.696 ± 0.005	17.68 ± 0.13	4
K_6	0.846 ± 0.005	21.49 ± 0.13	4
K_7	0.995 ± 0.005	25.27 ± 0.13	4
K_8	1.144 ± 0.005	29.06 ± 0.13	4
R	0.010 maximum	0.25 maximum	1

Approved March 14, 1950 by the American Standards Association Incorporated
Sponsor: Society of Motion Picture and Television Engineers Incorporated

*Universal Decimal Classification

American Standard

Location and Size of Picture Aperture of 8-Millimeter Motion Picture Projectors

ASA
Reg. U.S. Pat. Off.
Z22.20-1950
Revision of
Z22.20-1941
•UDC 778.55

The angle between the vertical edges of the aperture and the edges of normally positioned film shall be 0 degrees, ± ½ degree.

The angle between the horizontal edges of the aperture and the edges of normally positioned film shall be 90 degrees, ± ½ degree.

Note 1: Dimensions A, B, and R apply to the portion of the image on the film that is to be projected; the actual opening in the aperture plate has to be slightly smaller. The exact amount of this difference depends on the lens used and on the separation (dimension G) of the emulsion and the physical aperture. To minimize the difference in size and make the image of the aperture as sharp as practicable on the screen, G should be no larger than is necessary to preclude scratching of the film. When the reduction in size from the image to the actual aperture is being computed, it is suggested a 1-inch f/1.6 lens be assumed unless there is reason for doing otherwise.

Note 2: The limiting aperture is shown as being between the film and the light source so that it will give the maximum protection from heat. If other factors are more important, it may be on the other side of the film.

Note 3: In 8-mm. projectors the edge guide should bear on the edge of the film adjacent to the perforations. The other edge of the film usually is slit after processing and so is more likely to weave laterally with respect to the pictures.

The value of dimension C has been chosen so that film having a slight shrinkage when it is projected will be properly centered. This is the normal condition.

Note 4: The K dimensions are measured along the path of the film from the horizontal centerline of the aperture to the stopping position of the registration device. It is customary to provide a framing movement of approximately 0.025 inch above and below this nominal position. For any given projector, use the value of K corresponding to the location of the registration device.

If the film does not stop exactly where the film registration device leaves it, because of coasting or some other cause, a slight adjustment of the value of K will be necessary.

Note 5: "Optical axis of projector" is defined as the mechanical axis or centerline of the sleeve for holding the projection lens. Except for manufacturing tolerances, it coincides with the lens axis.

American Standard Dimensions for

Mounting Frames for Theater Projection Screens

ASA
Reg. U. S. Pat. Off
Z22.78-1950
*UDC 778.55

1. Scope and Purpose

1.1 This standard specifies dimensions for the mounting frames used for supporting motion picture theater projection screens.

2. Frame Size

2.1 Sizes of frames shall be in accordance with the table below.

2.2 The frame size shall be measured from the inner edge of one side to the inner edge of the opposite side.

2.3 Frames for use with screens of less than 12 feet x 16 feet require 3½ in. minimum clearance on each of the four sides with the minimum clearance increasing as indicated for the larger sizes.

3. Hooks

3.1 Suitable lacing hooks shall be provided on the inner edges of the frames. These hooks shall be spaced on 6¹⁄₃₂ in. centers starting at points 3 in. on either side of the center of the four sides of the frame.

Table of Frame Sizes

For Screen Size No.	Minimum Inside Dimensions of Frame					Over-All Screen Size Width Height				For Screen Size No.	Minimum Inside Dimensions of Frame					Over-All Screen Size Width Height			
	Ft	In.		Ft	In.	Ft		Ft	In.		Ft	In.		Ft	In.	Ft		Ft	In.
8	8	7	×	6	7	8	×	6		20	20	10	×	15	10	20	×	15	
9	9	7	×	7	4	9	×	6	9	21	21	0	×	16	7	21	×	15	9
10	10	7	×	8	1	10	×	7	6	22	23	1	×	17	7	22	×	16	6
11	11	7	×	8	10	11	×	8	3	23	24	1	×	18	4	23	×	17	3
12	12	7	×	9	7	12	×	9		24	25	1	×	19	1	24	×	18	
13	13	7	×	10	4	13	×	9	9	25	26	1	×	19	10	25	×	18	9
14	14	7	×	11	1	14	×	10	6	26	27	1	×	20	7	26	×	19	6
15	15	7	×	11	10	15	×	11	3	27	28	1	×	21	4	27	×	20	3
16	16	10	×	12	10	16	×	12		28	29	1	×	22	1	28	×	21	
17	17	10	×	13	7	17	×	12	9	29	30	1	×	22	10	29	×	21	9
18	18	10	×	14	4	18	×	13	6	30	31	1	×	23	7	30	×	22	6
19	19	10	×	15	1	19	×	14	3										

Approved March 14, 1950, by the American Standards Association, Incorporated

Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

American Standard Dimensions for

Mounting Frames for Theater Projection Screens

ASA
Reg. U. S. Pat. Off.
Z22.78-1950

Appendix

Projection screens for motion picture theaters are supplied in a variety of materials each of which has its own physical properties. One of these properties is the amount a screen of a given size will stretch after it is laced into a frame. For this reason it may be desired to provide mounting frames with more clearance than that specified in the table. The inside frame dimensions are specified as the minimum dimensions which will give a satisfactory installation when used with an average screen of the corresponding size.

Although frames suitable for mounting theater projection screens may be fabricated from any material of the required strength and rigidity, the following wood structural members are suggested:

For Screen Sizes from No. 8 to 11: 2 x 4 main members with 1 x 3 angle braces at the corners

For Screen Sizes from No. 12 to 19: 2 x 6 main members with 2 x 3 corner braces

For Screen Sizes from No. 20 to 30: 2 x 6 main members with 2 x 3 corner braces and two 2 x 4 vertical center braces spaced approximately 12 feet apart with the addition of a 2 x 6 approximately 12 feet long, reinforcing the spliced main members at top and bottom.

Note: For reference purposes the screen dimensions are also shown in the table. Complete information on screen sizes is given in American Standard Dimensions for Theater Projection Screens, Z22.29-1948.

American Standard for

16-Millimeter Sound Projector Test Film

ASA Reg. U. S. Pat. Off.
Z22.79-1950
*UDC 778.55

1. Scope and Purpose

1.1 This standard describes a film for qualitatively checking and adjusting 16-mm motion picture sound projection equipment and for judging the acoustical properties of the room in which the sound is reproduced.

2. Test Film

2.1 The film shall have a sound track and accompanying picture. The sound track shall comply with American Standard Sound Records and Scanning Area of 16-Mm Sound Motion Picture Prints, Z22.41-1946, and the film stock used shall be cut and perforated in accordance with American Standard Cutting and Perforating Dimensions for 16-Mm Sound Motion Picture Negative and Positive Raw Stock, Z22.12-1947, or any subsequent revisions thereof.

2.2 The test film shall contain samples selected from studio feature pictures in accordance with the American Standard for Theater Sound Test Film for 35-Mm Motion Picture Sound Reproducing Systems, Z22.60-1948, or any subsequent revisions thereof.

2.3 The assembled film shall contain picture reduced from the 35-mm sound test film, the dimensions of which shall comply with American Standard Location and Size of Picture Aperture of 16-Mm Sound Motion Picture Cameras, Z22.7-1941, or any subsequent revisions thereof.

2.4 The 16-mm release sound track shall be rerecorded from 35-mm original or release tracks through a rerecording channel, the electrical characteristics of which shall comply with current practices* in the industry in rerecording 35-mm feature releases for 16-mm release.

2.5 Each film shall be provided with suitable head and tail leaders. The main title shall include the issue number of the film so that revised versions which may be issued periodically to conform to changing studio practices or to changes in the reproducing characteristic of the 16-mm sound projectors may be easily identified.

2.6 Each film shall be accompanied by an instruction sheet indicating the procedure to be used in checking and adjusting 16-mm projection equipment.

2.7 The length of the film shall be approximately 200 feet.

3. Method of Use

3.1 From a typical location in the room where the sound is reproduced, the observer should determine whether or not the frequency response characteristics of the complete reproducing system are normal by listening to the sound reproduced from the test film when the tone control is set normal and the volume control is set to reproduce the dialogue at normal sound level.

3.2 If the picture and sound quality are displeasing and the dialogue unintelligible, then either:

(a) The equipment should be adjusted as shown in the technical manual provided by the manufacturer, or

(b) The room in which the sound is reproduced is not suitable.

Methods by which these factors may be determined should be included in the instruction sheet.

NOTE: A test film in accordance with this standard is available from the Motion Picture Research Council or the Society of Motion Picture and Television Engineers.

*See Motion Picture Research Council Practice for Rerecording 16-Mm Release from 35-Mm Release Sound Track N-1.1.

Approved March 14, 1950 by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Society Announcements

Frank E. Carlson of the General Electric Lamp Division in Nela Park, Cleveland, and **Malcolm G. Townsley,** Vice President in Charge of Engineering of the Bell & Howell Co., Chicago, have been appointed Society Governors for the current year. On March 23rd, E. I. Sponable, President, announced that these two appointments had been made by unanimous consent of the Board of Governors. The vacant terms were created by the amended Constitution that became effective at the beginning of 1950.

William F. Little, long a member of our Society, and Engineer in Charge of the Photometric Dept. of Electrical Testing Laboratories, Inc., New York, has been selected to receive the 1950 Gold Medal of the Illuminating Engineering Society. The medal, to be presented formally during the I.E.S. National Technical Conference at Pasadena, Calif., August 21–25, is being awarded "for meritorious achievement conspicuously furthering the profession, art or knowledge of illuminating engineering."

Mr. Little's work in the field is well known to motion picture engineers who have studied seriously the questions of projection lighting, screen brightness and screen reflectivity characteristics. Many have looked to him for counsel and advice or otherwise drawn heavily on his fund of knowledge or experience, and all will extend their congratulations.

The Society's Constitution and Bylaws are omitted from this year's April Journal, contrary to recent practice, because the Bylaws are in process of amendment and are to be voted on at the 67th Convention in Chicago. The Proposed Bylaw Amendment was introduced and published in full in the March Journal, pp. 367–374. Both Constitution and Bylaws will appear in the May issue.

Members acquainted with the military photographic services will be interested to learn that Col. William W. Jervey, who has been in charge of the U.S. Army Signal Corps photographic activities since September, 1945, has left the Pentagon for Germany. His place as Chief, Army Pictorial Service Div., Office of the Chief Signal Officer, has been taken by Col. Charles S. Stodter, former Commanding Officer of the Signal Corps Photographic Center, Long Island City, N.Y. Lt. Col. Wallace W. Lindsay has assumed command of the Signal Corps Photographic Center.

The Armed Forces Communications Association holds its annual convention at the Commodore Hotel, New York, on Friday, May 12. On Saturday, May 13, the Army Signal Corps and AFCA will present an extensive open house tour of the Signal Corps Engineering Laboratories, the Armed Services Electro-Standards agency and the Signal School, all at Fort Monmouth, N.J. Exhibits will feature important highlights of the work being done by the Communications Services in extensive co-ordination with the manufacturers who supply equipment and industrial research and development laboratories that furnish technical services. If weather permits there will be parachute drops by the 82nd Airborne Division,

demonstrations of wire laying by helicopter and bazooka. Inquiries about this elaborate program should be directed to Col. George P. Dixon, Executive Secretary, AFCA, 1624 Eye St., Connecticut Ave., N.W., Washington 6, D.C.

Student Members

Applications for Student memberships have been coming in at a gradually increasing rate during recent months. This is encouraging to the officers of our two Student Chapters and shows a growing interest on the part of college students in a number of motion picture film courses currently being offered.

In the past, Student memberships have been recorded on a calendar year basis, along with the other grades of memberships; but beginning in March, 1950, all new Student memberships will date from September 1st and continue on a school-year basis. Appropriate arrangements will be made this year so that each member in the Student grade will receive full credit for dues paid and on September 1st they will all be billed for the period from January through August, 1951. All expirations will then occur at the beginning of each new school year.

Engineering Committees

Television

Television broadcasters have had their share of troubles over the past two or three years in adapting motion pictures as a source of television program material. The initial mechanical problems of converting 24-frames/sec motion pictures to 30-frames/sec images for the iconoscope or image orthicon pickup cameras have been generally solved, at least to the extent that results are commercially acceptable. The future is encouraging since several research projects are now moving rapidly toward much improved reproduction of the picture, but acres of virgin territory remain. Characteristics of the ideal television film, mechanical improvements in projection equipment, special television film leaders, cue marks and aperture sizes are a few of the unsolved problems.

In a combined effort to ease the industry's burden, the Society, the Institute of Radio Engineers, and the Radio Manufacturers Association have under discussion a program for the co-ordination of television projects. The major aim is to eliminate duplication of effort that results when engineers are asked to serve on committees of more than one organization working on the same subject or closely related ones. Overlapping committee rosters could be replaced by interlocking memberships so that a minimum of "co-ordination" effort would keep all concerned posted on current progress.

Preliminary plans were considered at a meeting held in New York on March 22nd. The Society was represented by F. T. Bowditch, Engineering Vice President, Boyce Nemec, Executive Secretary, and W. H. Deacy, Staff Engineer; the IRE by Axel Jensen and IRE-RMA co-ordination by M. W. Baldwin. It was agreed that the formation of a correlating body would be recommended on which the IRE, RMA and SMPTE would be represented. This group would allocate new projects as they arose to the organization best qualified.

To implement the Society's share in this project, a major reorganization of the Society's Television Committees and reassignment of projects were announced on March 22nd by Mr. Bowditch. Two of the groups that will replace the former Television Committee are the committees on Television Studio Lighting and on

Films for Television. Others will be formed as required. The Society's long standing Theater Television Committee will continue without change on its work with the motion picture producers, exhibitors, the common carriers and the Federal Communications Commission. Memberships and scopes of these committees are shown in the roster of Society committees elsewhere in this JOURNAL.

Current Literature

THE EDITORS present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 31, no. 1, January, 1950

Economy Lighting with Photofloods (p. 10) F. FOSTER

Carbon Arc Studio Lighting (p. 11) W. W. LOZIER

The Production of Films for Television (p. 12)

Rating Color Temperature (p. 13) D. NORWOOD

New Multiple Sound Track for 16mm Films (p. 14) L. ALLEN

Lighting for Color Movies (p. 16) C. LORING

British Kinematography

vol. 15, no. 6, December, 1949

Improvements in Large Screen Television Projection (p. 178) T. M. C. LANCE

Discharge Lamps in Relation to Film Projection (p. 191) A. G. PENNY

vol. 16, no. 1, January, 1950

A Small Continuous Processing Machine for Experimental Work (p. 2) G. I. P. LEVENSON

The Film in Relation to Agricultural Engineering (p. 9) D. HARDY

Standardization and the Kinema:

Introduction (p. 17) S. B. HARRISON-SWINGLER

Standards and the Exhibitor (p. 18) L. KNOPP

Standards for Projection Equipment (p. 18) S. A. STEVENS

International Standardization (p. 19) C. H. BELL

Standardization Combats Film Mutilation (p. 20) R. H. CRICKS

Electronic Engineering

vol. 22, no. 1, January, 1950

Recording of Television (p. 8)

Electronics

vol. 23, no. 1, January, 1950

Dot Systems of Color Television (p. 96) W. BOOTHROYD

International Photographer

vol. 21, no. 12, December, 1949

New Type Variable Area 16mm Track, Introduced by J. A. Maurer, Inc. (p. 22)

Bell & Howell Camera Records Life at Greatest Sea Depth (p. 22)

vol. 22, No. 2, February, 1950

Three Dimensional Photography (p. 12) A. WYCKOFF

Motion Picture Films in TV (p. 18)

International Projectionist

vol. 25, no. 1, January, 1950

The 35-mm Projection Positive Film, Pt. III, (p. 5) R. A. MITCHELL

Theatre Television: What, How and When (p. 13) J. E. McCOY and H. P. WARNER

vol. 25, no. 2, February, 1950

The 35-mm Projection Positive Film, Pt. IV, (p. 7) R. A. MITCHELL

The New Simplex X-L 35-mm Projector Mechanism (p. 14)

Kinematograph Weekly

vol. 394, no. 2224, December 15, 1949

Colour Developments Reviewed (p. 63) J. H. COOTE

Independent Frame Process Puts Film Making on Factory Basis (p. 67) R. H. CRICKS

How to Choose a Projector (p. 144) J. COOPER

Book Review

Noise and Sound Transmission, Report of the 1948 Summer Symposium of the Acoustics Group

Published (1949) by The Physical Society, 1 Lowther Gardens, Prince Consort Road, London S. W. 7. 200 pp. 130 figs. 20 tables. Paper bound, 7 × 10 in. (This publication is available from the Acoustical Society of America, 57 E. 55th St., New York 22, for $2.75 including postage and handling charges. Remittances should be sent with the orders and should be made out to the Acoustical Society of America.)

We are indebted to the Acoustics Group of The Physical Society (London) for the publication in this book of 41 papers on sound transmission and noise presented by a gathering of experts from twelve countries. Although the principal emphasis in most of the papers is on the insulation of sound in homes and apartments, there are also reported in the volume fruitful studies of the nature of air-borne and impact sounds, recommended standard and field methods of measuring the sound insulation of floors, walls, windows and other partitions, and a variety of other related topics.

Some findings reported at the symposium, of interest to motion picture and radio engineers, are the following:

"...double glazing (of windows) is slightly worse acoustically than single glazing of the same total superficial weight...There is no acoustical advantage in fitting glazing heavier than about '24 oz.' unless the opening sections of a window have a very good closure." [G. H. Aston]

"The reduction of the stiffness of thin panels increases their sound insulation." [L. Cremer]

"The loudness levels in phons of some typical complex noises are shown to be 3 to 17 phons greater than the corresponding sound levels in decibels as determined by a sound level meter." [A. J. King]

"In England, the noise from the banging of the neighbors' doors appears to be more troublesome than that from their radios." [W. A. Allen]

A reading of the papers presented at the symposium reveals that at least in the construction of residental flats and apartments, the Europeans are making more progress than we are in the control and insulation of noise. Anyone interested in noise and sound insulation problems will find practical solutions to many of these problems in *Noise and Sound Transmission.*

Vern O. Knudsen
University of California
Los Angeles 24, Calif.

Journals Available

The following 33 back numbers of the Journal, and one Index, are available at the job lot price of $25.00 from Mr. E. W. Noli, Pacent Engineering Corp., 79 Madison Ave., New York 16.

1931, Dec. 1932, Jan.–Dec. 1933, Jan.–Dec. 1934, May–Dec.
Index for 1930–35

New Products

Further information concerning the material described below can be obtained by writing direct to the manufacturers. As in the case of technical papers, publications of these news items does not constitute endorsement of the manufacturer's statements nor of his products.

RCA's new industrial television system consists of two units: an 8-lb TV camera and a master control monitor about the size of a suitcase. The camera is 10 in. long, 3 in. wide and 5 in. high. It has only three tubes, including the newly developed Vidicon pickup tube which is about 1 in. in diameter and 6 in. long. The Vidicon is based on the principle of photoconductivity, rather than employing photoemissive cells as used by the image orthicon and other pickup tubes in general use. Ordinary 16-mm motion picture lenses are used. The camera has a remote focusing mount, which permits the operator to adjust optical focus by remote control from the master control unit.

The system operates on 110-v, 60-cycle alternating current and consumes 350 watts. It is reported capable of transmitting a signal 250 ft over a coaxial cable closed circuit. It has a scanning frequency of 525 lines, 60 frames interlaced, and is compatible with standard television broadcasting techniques.

The master control unit of the system is 24 in. long, 15 in. high, 8¼ in. deep and weighs 58 lb. It contains a regulated power supply, small synchronizing signal generator, a video amplifier strip and all the scanning deflection equipment

for both the camera and its own 7-in. monitoring kinescope. It contains 44 tubes.

By providing safe and convenient viewpoints, it is expected that this system will prove an aid to education and industrial efficiency. The RCA Engineering Products Dept., Camden, N.J., has issued a bulletin, ITV-1, which gives an over-all description of possible uses. RCA has noted that installation of the system could prevent such episodes as the robbery of the Brink vaults in Boston, and the first public demonstration was that of monitoring prisoners in the City Prison of Manhattan. For job training in industry and educating in the armed forces, schools and hospitals, the system will present demonstrations, close-up views of experiments or enlargements of microscopic studies. In industry, products may be inspected and processes watched in positions or environments insufferable or inconvenient for immediate human attendance.

Meetings of Other Societies

Institute of Radio Engineers, Cincinnati Section, Spring Technical Conference on Television, April 29, Cincinnati, Ohio

Institute of Radio Engineers, Technical Conference, May 3–5, Dayton, Ohio

Armed Forces Communications Assn., Annual Meeting,
May 12, New York, and Long Island City
May 13, Fort Monmouth, N.J.

Acoustical Society of America, Spring Meeting, June 22–24, State College, Pa.

Illuminating Engineering Society, National Technical Conference, August 21–25, Pasadena, Calif.

Employment Service

POSITIONS WANTED

In Manufacturing: Broad experience in developing, improving and producing of home movie cameras and projectors. Good technical background. Desire position with mfr. Earle F. Orr, 345 Fellsway West, Medford, Mass.

With 35-Mm Production Unit: Young veteran desires to learn motion picture production. Will work in any capacity. Single, 23, with 8 yr theater experience, all phases; mgr small house 3 yr; 2 yr A.M.P.S. projectionist supervisor; grad. AAF Photo School and Motion Picture Inst. production course. Have private library of over 200 film books; serious student of films since 15. Currently employed; detailed letter and refs readily supplied; salary no object. John P. Lowe, 265 State St., Northampton, Mass.

Producer-Director-Editor: 10 yr with major film producers. Thorough knowledge and experience script-to-screen production technique: directing, photography, editing, laboratory problems, sound recording, 35- and 16-mm, b & w. Specialist in research and production of educational and documentary films; small budget commercial and TV films. Long experience in newsreels. Desire greater production possibilities, go anywhere. Member SMPTE, top refs. E. J. Mauthner, P. O. Box 231, Cathedral Sta., New York 25.

POSITIONS WANTED

TV and Motion Picture Engineer: 3 yr experience in motion picture engineering and research at Philips Physical Laboratories, Eindhoven; 6 yr as TV-Director, same firm; 3 yr as Director of Decca plant in Belgium. Desires assignment in any part U.S.A. Highest qualifications and references U.S. firms. Write Fernand Beguin, c/o Mr. Marc Albanese, 416 Madison Ave., New York 17.

In technical phase: Motion picture or still photography. 4 yr experience in research, development, and testing, both color and b & w films. Graduating from M.I.T. June, 1950. Member, SMPTE. W. A. Farmer, 141 Grand Ave., Rochester 9, N.Y.

Cameraman-Director: Currently employed by internationally known producer, desires greater production opportunities. Fully experienced 35- and 16-mm, color, b & w; working knowledge editing, sound, and laboratory problems; administrative experience. Top references and record of experience available. Write P.O. Box 5402, Chicago.

Cameraman: Trained with practical experience in 16-mm and 35-mm equipment & technique with prominently successful men in the industry. Thoroughly familiar with B & H Standard, Mitchell, Eyemo, & Filmo cameras, Moviolas, etc. Thorough knowledge & experience script-to-screen production technique; directing, editing, photography, film evaluation, production, treatments, shooting-scripts, small budgets, documentary & theatrical production. Go anywhere. Age 33. Top industry & character references furnished confidentially. Anxious for position where ability, sincere interest and creativeness offer opportunity. Active Member of SMPTE. Write Milton L. Kruger, R.F.D. 1, Ridgewood, N.J.

SMPTE Officers and Committees: The roster of Society Officers is scheduled for publication in the May JOURNAL. The Committee Chairmen and Members are shown in this issue. Changes in these listings are scheduled for the September JOURNAL.

SMPTE HONOR ROLL

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased.

Louis Aimé Augustin Le Prince
William Friese-Greene
Thomas Alva Edison
George Eastman
Frederic Eugene Ives
Jean Acme Le Roy
C. Francis Jenkins
Eugene Augustin Lauste
William Kennedy Laurie Dickson

Edwin Stanton Porter
Herman A. DeVry
Robert W. Paul
Frank H. Richardson
Leon Gaumont
Theodore W. Case
Edward B. Craft
Samuel L. Warner
Louis Lumiere
Thomas Armat

HONORARY MEMBERS

Lee de Forest

A. S. Howell

Committees of the Society

As of April 1, 1950

ADMINISTRATIVE COMMITTEES

ADMISSIONS. *To pass upon all applications for membership, applications for transfer, and to review the Student and Associate membership list periodically for possible transfer to the Associate and Active grades, respectively. The duties of each committee are limited to applications and transfers originating in the geographic area covered.*

E. A. Bertram, *Chairman, East,* DeLuxe Laboratories, 850 Tenth Ave., New York 19, N.Y.

R. B. Austrian, Herbert Barnett, H. D. Bradbury, Richard Hodgson, C. R. Keith, W. H. Rivers

G. E. Sawyer, *Chairman, West,* Samuel Goldwyn Studio Corp., 1041 N. Formosa Ave., Hollywood 46, Calif.

C. R. Daily, George Friedl, Jr., L. D. Grignon, J. P. Livadary

BOARD OF EDITORS. *To pass upon the suitability of all material submitted for publication, or for presentation at conventions, and publish the* Journal.

A. C. Downes, *Chairman,* 2181 Niagara Dr., Lakewood 7, Ohio

M. R. Boyer, L. F. Brown, A. W. Cook, J. G. Frayne, A. M. Gundelfinger, C. W. Handley, A. C. Hardy, P. J. Larsen, G. E. Matthews, Pierre Mertz, J. H. Waddell

CONVENTION. *To assist the Convention Vice-President in the responsibilities pertaining to arrangements and details of the Society's technical conventions.*

W. C. Kunzmann, *Chairman,* National Carbon Division, Box 6087, Cleveland 1, Ohio

G. W. Colburn, C. R. Daily, E. R. Geib, H. F. Heidegger, L. B. Isaac, O. F. Neu, E. S. Seeley, N. L. Simmons, R. T. Van Niman

EUROPEAN ADVISORY COMMITTEES. *To act as liaison between the general Society and European firms, individuals, and organizations interested in motion picture and television engineering. To report to the Society on such affairs in Europe, on new technical developments, and to assist the Papers Committee in soliciting papers for publication in the* Journal.

I. D. Wratten, *Chairman (British Division),* Kodak, Ltd., Kingsway, London, England

R. H. Cricks, W. M. Harcourt, L. Knopp, A. W. Watkins

L. Didiée, *Chairman (Continental Division)* Association Française des Ingénieurs et Techniciens du Cinéma, 92 Champs-Elysées, Paris (8e), France

R. Alla, R. Bocquel, M. Certes, J. Cordonnier, S. Feldman, J. Fourrage, G. Mareschal, M. Terrus, J. Vivié, M. Yvonnet

FELLOW AWARD. *To consider publications of Active members as candidates for elevation to Fellow, and to submit such nominations to the Board of Governors.*

L. L. Ryder, *Chairman*, Paramount Pictures, 5451 Marathon St., Hollywood 38, Calif.

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Progress Committee Report

Much of the progress in the motion picture studios during 1949 is traceable to a determination for greater economy in production without altering the box-office drawing power of the product. Some of the techniques and equipment which have been received primarily on an economy basis would have been accepted on any other basis because of their apparent value; others have found limited use as a perusal of this report will show. A résumé of the articles and papers listed in the references indicates that, while some care has been taken that the new techniques do not reduce box office value, they have had considerable influence on the type of productions made.[1–4]

A number of the points of progress in the era of the economy move are so simple as to have been overlooked when total picture cost was not such an alarming factor. An example is the movement of horses to western picture locations where a second cab has been placed on the prime mover of the truck-trailer combination to accommodate the wranglers who formerly used a separate automobile to follow the truck.

Progress in picture and sound reproduction is highlighted by successful efforts to provide more screen light for large indoor and drive-in theaters.

In the television field there is a distinct movement toward the application of motion picture studio techniques as a transitory stage leading toward the perfection of television techniques as such. Whereas in the past television has been restricted to a large extent by the space limitations of the radio broadcasting studio it is now expanding to the motion picture studio types of buildings where it is possible to have permanent sets and to utilize many of the process tricks of motion picture production which help to provide realism.

35-Mm Photography

Progress in the fields of motion picture film, cameras, and studio lighting is again largely a consolidation of the use of techniques and equipment previously announced.

Documentary style pictures which make use of natural locations and low-key effect lighting came as a part of a shift in production techniques. Color has gone to the locale of the story and the motion

Submitted: March 21, 1950.

picture trade journals report American color productions in Utah, Arizona, England, Italy, Belgian Congo, India and Africa. Production in the West Coast studios has been sporadic.

Preplanning of the motion picture has gained some headway. In Great Britain the "Independent Frame" technique, whereby the picture is preplanned frame by frame, has created considerable interest and has resulted in some pictures being made under that system.[5] Production in the United States is moving toward preplanning on the basis of evolution, rather than revolution, in order to avoid loss of spontaneity and emotional effect in the finished product.

Considerable additional use has been made of the latensification process as a means of reducing the cost of producing motion pictures.[6,7] It is claimed that since latensification permits lower levels of light intensity, the over-all production can be conducted at a faster pace. The latensification and resulting development processes produce an increase in graininess of the film. Under certain conditions improved photographic quality is claimed for the latensification process in that it enables the exposures to be made using smaller camera stops than would otherwise be the case.

In the United States the low shrinkage safety base film of the triacetate type, introduced by Eastman Kodak Co., has been received with considerable favor. It is currently being used for release prints and studio work prints.[8] There has been some application as a sound recording negative and experiments are in progress to determine its adaptability to picture negative films. While the prime purpose of the use of safety film is to decrease operating hazards, the economies effected by its use are of considerable magnitude, from reduced building costs and simpler equipment to lower insurance charges and transportation.

A Signal Corps project with Armour Research Foundation of Illinois Institute of Technology is in its second year covering development of film bases suitable for use over a wide temperature and climate range. Several apparently satisfactory materials have been found and are being developed.

Another project by the same group is directed toward evaluating the fundamental factors pertaining to the use of diazo compounds for the preparation of photographic films with speed and range. The objective of this program is a new high-speed processing that will yield direct positives with a simple one-step development procedure.

The Interagency Advisory Committee for Nitrate Film Vault

Tests has continued its work during 1949.[8a] Tests conducted by the National Archives and Record Service, co-operating with the National Bureau of Standards and the motion picture industry, have led to definite conclusions. Results of the 1948 tests led to the preparation of specifications and the manufacture of improved film storage racks of both open and closed types. Thorough tests of the new racks, with various types of water sprinkler systems, and tests with no water, have shown that the rack design is highly successful in holding the film loss to a negligible degree. This is especially true with the closed rack design. The tests also indicated that smoke detection equipment was of little value in preventing loss. Other tests conducted by this committee on the decomposition of nitrate film have shown that nitrate film in the third and fourth stages of decomposition will spontaneously ignite at temperatures as low as 120 F.

The Photo Research Corp. and the W. M. Welch Manufacturing Co. have announced photoelectric densitometers of interest. The former is intended for color use by means of filters. The Welch Densichron is notable for its accuracy and stability as a result of a-c field modulation of the cell.

Color Processes

The Ansco process has been further developed and has received additional commercial use. A complete line of film types is now available for all of the necessary steps from original taking film through the duping and special effects steps to release prints.

Du Pont has introduced a positive film for making three-color prints from separation negatives.[9,10] This film is notable in that it employs a synthetic polymer which combines the functions of the gelatine and the color formerly usually employed. There has been little if any commercial use of this film.

Eastman has introduced, on an experimental basis only, a 35-mm negative-positive color process. This involves a camera negative film which yields a complementary color negative, with integral color masks, which is printed onto a color print film yielding a positive color print. The color print film may also be used with separation negatives. The color forming couplers are incorporated into the print film.

Both Eastman and Du Pont have been experimenting with a negative film which involves the use of three emulsions, two of which are

subsequently stripped from the original base and mounted on new film bases in the laboratory before development. Although various problems connected with this process are not completely solved, both companies successfully performed the operation on considerable quantities of film. There are no known commercial uses of the process.[11]

A three-color printing method was described for the Cinecolor process.[12]

Lighting Equipment and Techniques

Carbon Arcs. Carbon trims for the MR "Brute" lamp which operates at 225 amp have been modified to reduce noise level both at striking and during burning periods.[13]

Incandescent Bulbs. The reflector type of incandescent lamp, of which the photoflood and photospot are examples, has found added use particularly on documentary type and other pictures where low-level effect lighting is indicated.

Mercury-Cadmium Lamps. The mercury-cadmium lamp, called the compact source lamp in England where it was first developed, has been slow in achieving acceptance by the British motion picture industry. It is now being used, to a limited degree however, for both black-and-white and color photography. Lamps are available at 2½ and 5-kw ratings with a few 10-kw lamps available on an experimental basis.

Samples of 5-kw mercury-cadmium lamps, operating at approximately 70 amp at 70 arc volts, have been delivered by American manufacturers to interested companies in Hollywood.[14–16]

Cameras and Accessories

A new portable camera, called Camerette, manufactured by Etablissements Cinematographiques Eclair of France, was introduced in Great Britain and Europe in 1948 and in the United States in 1949. Coupled with the light weight of the camera, its instantaneously interchangeable magazines and reflex viewing, is a double pull-down movement with an ingenious system of pressure pads and spring guides to insure steady operation.[17]

A new electronic shutter analyzer employing a two-gun cathode-ray oscilloscope with two phototubes has been developed by the Navy.[18] This device is designed to permit the rapid analysis and solution of numerous problems commonly encountered in photography including: analysis of motion picture camera shutters; cali-

bration of frame-per-second tachometers; shutter-flash synchronization; diaphragm calibration; duration and intensity of light emitted by flash bulbs and some gaseous discharge tubes.

Set Construction

Translucent Photographic Backings. Perhaps one of the most interesting developments is a new photographic backing introduced by M. P. Paul of Hollywood. This backing is available in fairly large sizes, either black-and-white or in full color. It is translucent and permits novel and realistic effects to be obtained by lighting from the back. Single photographic enlargements on seamless, translucent sheets are produced in sizes up to 20 × 45 ft.[19,20]

A number of studios are making more and better use of steel scaffolding as an underpinning for elevated sets. It is claimed that savings as high as 80% are possible over the wood type of semipermanent construction.

Scotchlight, a highly reflective material, is sometimes used in windows and doors to indicate that light is coming through from outside, or from another room in the case of doors.

There was considerable activity in the application of new plastic materials to the various phases of set construction. These include breakaway glass, combinations of plaster and plastic, low-temperature thermosetting plastics for casting ornamental objects of various types, lightweight tree trunks, building columns, sections of trains and many other similar applications (Fig. 1).

There has been developed and is in regular use in most of the Hollywood studios, a strippable adhesive for use with wallpaper and temporary flooring such as linoleum or asphalt tile. In both applications, this adhesive affords the easy removal of the surface material after its use.[21]

16-MM AND 8-MM PHOTOGRAPHY

Papers and reports on high-speed photography have completely filled two issues of the JOURNAL during 1949 providing an excellent reference work for the subject.

Advance in the employment of high-speed photography in the Army, Navy and Air Force during 1949 was notable. This was not so much in the improvement in equipment as in the expansion of the applications, techniques and fields of usage of high-speed photog-

Fig. 1. Plastic and wood locomotive used by 20th Century-Fox for their picture "A Ticket to Tomahawk."

Fig. 2. Series of coated lenses, from left to right: .7-in. T2.7 ($f/2.5$) Bell & Howell Super Comat; 2-in. T1.6 ($f/1.4$) Taylor Hobson Cooke Ivotal; 2.8-in. T2.5 ($f/2.3$) Taylor Hobson Cooke Panchrotal; and 4-in. T2.5 ($f/2.3$) Taylor Hobson Cooke Panchrotal.

raphy. In research, development and testing of new weapons and equipment, high-speed photography has proven a valuable tool.

Extensive ballistic data on long-range and guided missiles in the Army Ordnance Department's missile program at White Sands Proving Ground are obtained with the extensive use of motion pictures.[22] Tracking telescopes have been developed which are in effect motion picture cameras of very long focal lengths. Telescopes up to 16-in. size, and focal lengths up to 80 ft have been used. Stationed 40 miles from the launching site at an elevation of 8,000 ft, these instruments have photographed V-2 missiles and furnished their trajectories to an altitude of approximately 35 miles. Orientation of the axis of a V-2 missile at an altitude of 20 miles has been determined with a probable error of 0.6 deg.

A pressurized ballistics range has been installed at the Naval Ordnance Laboratory which will permit the study of aerodynamic characteristics of missiles at different Reynolds numbers, and will lead to a better correlation between small models and full-scale data. The range is located in a steel tube, 3 ft in diameter and over 300 ft long. Pressure up to five atmospheres and down to one-hundredth of an atmosphere can be obtained. Twenty-five photographic stations are located along the tube to photograph the missile by the direct shadowgraph method using high-speed flash actuated by the missile as it passes between a source of light and a photocell. An electronic chronograph measures the time intervals between stations.[23]

During the past year a number of 16-mm and 8-mm cameras and projectors intended for the amateur trade were introduced by various manufacturers. Of particular interest to the professional trade were a new Bell & Howell Design 2709 16-mm camera. This resembles the standard 35-mm Bell & Howell camera with the Unit I shuttle. The Nord Co. announced a professional camera, and Pathé Cine, a division of Director Products, Inc., announced a new Pathé Super 16 Camera.

A new view finder, announced by the French Emel Co., covers a field ratio from 1 to 8, whereas the finder image remains 33 × 44 mm regardless of the change in field.

Bell & Howell has announced a new series of coated lenses for 16-mm cameras developed in co-operation with Taylor Hobson, England (Fig. 2). These lenses are supplied with click stops. The focal lengths of the series are chosen to provide uniform magnification

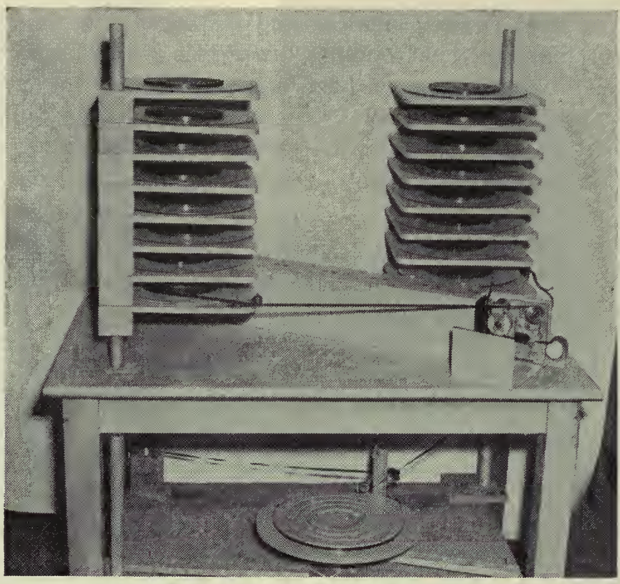

Fig. 3. Multiple duplicator for contact printing magnetic recordings.

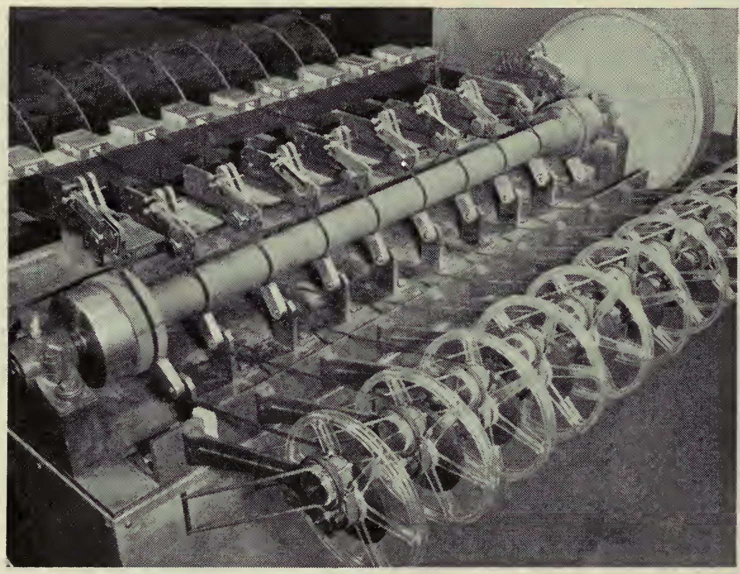

Fig. 4. Multiple track magnetic tape duplicating machine.

steps. Of particular importance is the improvement of corner resolution in the new series.

Western Electric and Wollensak have announced a new objective series and finder improvements for the Fastax high-speed cameras.

35-MM SOUND RECORDING

Magnetic recording is gradually being integrated into the production of motion pictures in England, Europe and the United States. Its freedom from photographic and developing distortions, the possibility for somewhat smaller and lighter recording equipment, and operating economies are the factors stimulating its use.

A number of new magnetic recording and reproducing devices were introduced, such as the modification of theater-type soundheads for magnetic reproduction, and combination photographic and magnetic recorders and reproducers.[24] Westrex and RCA modifications were available to convert photographic recorders, soundheads, and film phonographs for both photographic and magnetic film.

Completion of a contact printing process for magnetic recordings was announced by Marvin Camras of Armour Research Foundation of Illinois Institute of Technology and one of its licensees, Minnesota Mining & Manufacturing Co. (Fig. 3). The method permits faithful duplication at high speed and in large quantities from pre-equalized master type. The master is held in contact with a blank tape while the two are passed through a "transfer field." Upon separation of the copy tape from the master, it retains an accurate reproduction. The method is applicable to discs also.

An eight-tape single master tape printer will produce more than 960 hr of recording per day. Of particular interest is the economy of the magnetic printing process, as the master does not deteriorate during use. No further processing of the copy is required. The speed or "exposure" during printing is not critical.[25]

The Minnesota Mining & Manufacturing Co. announced a multiple track magnetic tape duplicator using conventional recording technique simultaneously on several tapes (Fig. 4).[26]

Warner Brothers Pathé News have made use of RCA's magnetic recording facilities to speed up the final preparation of newsreel material by the editing office, as well as to improve the sound quality of newsreel releases.

Paramount Studios have been using a magnetic sound recording channel for production shooting, the entire weight of which has been

reduced to under 150 lb. Utilization of magnetic recording is being expanded and within a year all production, scoring and dubbing recording will be on magnetic film. Photographic films will continue to be used for sound negatives and for release prints.

Columbia Studios soon expect to go into a method of re-recording in which multi-track 35-mm magnetic film will be used as the medium for storing various dubbing components, for later use in the dubbing of foreign versions, television versions, 16-mm versions and normal domestic release.

Dubbing consoles are being rewired so that the dubbing output is divided into four channels: a dialogue channel, a music channel, a sound effects channel and an over-all channel, including the normal dubbing output. The first three channels will feed the three tracks of a multi-track magnetic recorder. The last channel will feed a normal film recording channel.

When the dubbing is made, the first three channels will be used to store the result on a single 35-mm magnetic film. When a satisfactory take has been obtained it will be transferred to film from the magnetic tape, eliminating the recording of worthless takes.

The magnetic film will then be stored for the future dubbing of various versions which will be obtained by transferring the desired number of sound tracks from the magnetic film to photographic film.

This procedure will result in the elimination of worthless dubbing takes, reduction in the dubbing time and cost of foreign versions, and the improvement in quality of all dubbed versions. It will simplify the work of supplying the laboratory with identical duplicate negatives and will reduce storage space by a factor of 15 to 1 where the original dubbing material must be stored.

A new miniature condenser microphone and associated amplifier has been introduced in Hollywood by the Altec Lansing Corp.[27] It is a high-quality instrument and is nondirectional. Its application in the motion picture studios in Hollywood has thus far been limited to music recording.

The RCA MI-10001 microphone has been further improved by the addition of a fine mesh magnetic screen which is located in front of the ribbon and screens out foreign particles which are apt to become lodged in the air gap. This screen also reduces wind noise effects.

Among the items announced by Westrex Corp. during 1949 are:

(1) A precision motor speed control using a special duplex-type crystal as a reference to maintain a speed accuracy equivalent to

better than ⅔ of a frame in 500 ft.[28] Two or more of these units allow the sound recorder and camera(s) to be operated from completely independent power sources and yet obtain effectively synchronous performance.

(2) A variable-area modulator to be used in the Westrex portable recording system.[29] A new optical system making use of reflecting surfaced light valve ribbons enables the recording of direct positive as well as negative variable-area sound tracks.

35-MM PICTURE AND SOUND REPRODUCTION

The demand for increased light for large screen projection used in the major indoor and drive-in theaters has resulted in the announcement and application of new projectors, carbon arc lamp houses, faster optics and improved carbon trims.

The problem of film heat tolerance which was the bottleneck limiting the use of these advancements was given considerable attention on the basis of compressed air on the film, heat filters in the light beam of both absorption and reflection types, and water-cooled aperture units. Installations of equipment using these various means of cooling have been made in numerous locations and they are now being evaluated according to their respective merits.[30–33]

Improvements in projectors include opening of the systems for the faster $f/2.0$ and $f/1.9$ objective lenses and increased shutter transmission.

Improvements in carbon arc lamp houses include better auxiliary magnetic control of the arc flame, arc positioning devices, improved ventilation and, in the case of mirror type lamps, faster and more accurate mirrors.[34–36]

New objective lenses with speeds to $f/1.9$ in focal lengths from 5 to 7 in. have been placed on the market.

Carbon trims of higher intrinsic brilliancy for operation up to 180 amp and designed for the faster optics and greater heat tolerance are being introduced.[37]

The total improvements will allow for double the screen light of that formerly used in many cases.[38]

A portable device for measuring radiant energy at the projector aperture was described.[39]

Considerable work has been done by the Research Council, Inc., Eastman Kodak Co., National Carbon Division of Union Carbide & Carbon Corp. and others toward the dissemination of information

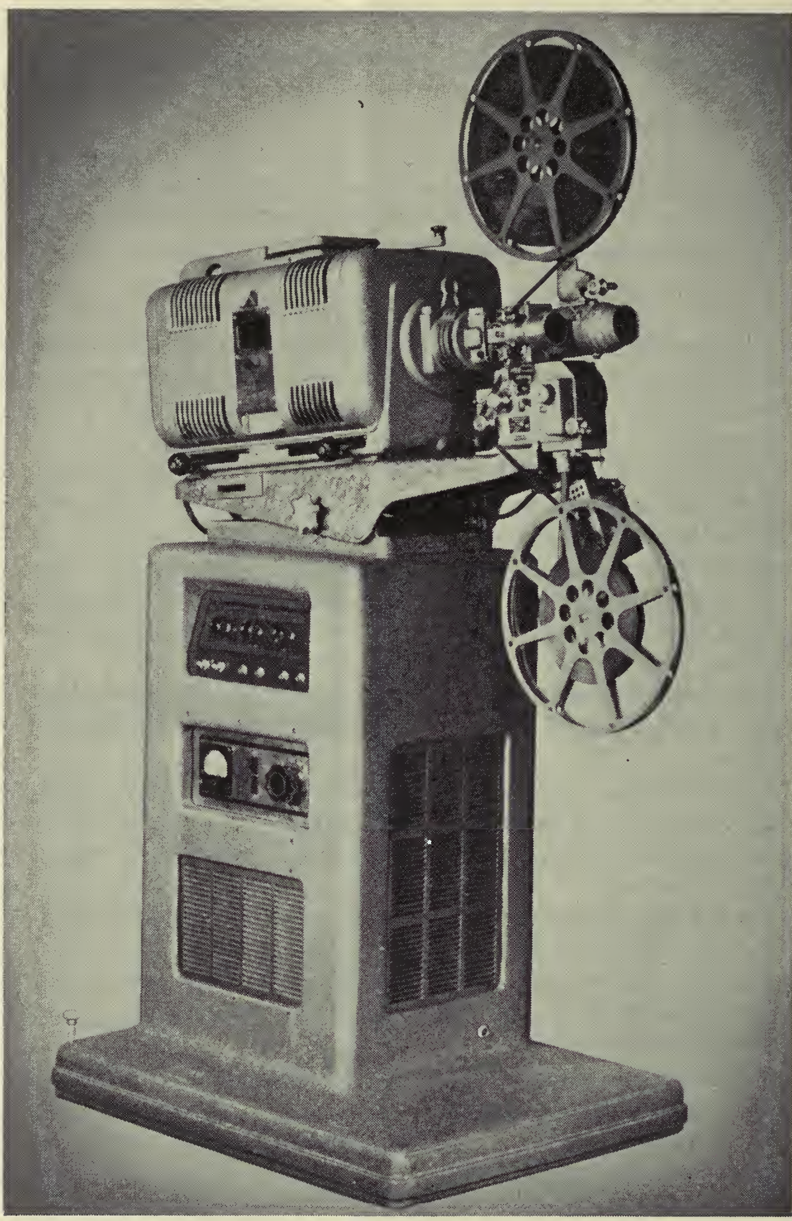

Fig. 5. Bell & Howell's Filmoarc Model 140 U with amplifier and rectifier completely housed in streamlined base. Connecting cables are concealed for smooth exterior appearance.

which will provide better co-ordination between set lighting, auditorium illumination and projection light.[40]

Projection optical train alignment devices have been placed on the market by a number of carbon arc lamp manufacturers.

Attention has been given to screen surfaces and nonperforated screens of cotton and fibre glass have been placed on the market. The makers claim greater reflectivity without distortion due to sound absorption.

A new light source developed by the Western Union Co. is an open arc between zirconium cored nickel electrodes. This arc has electrical characteristics and other features similar to the low-intensity carbon arc. Long electrode life is a stated advantage.

16-MM REPRODUCTION

In the field of 16-mm projection, the Bell & Howell 16-mm carbon arc has a reflector of rhodium, giving 1300 lumens output. The announcement of a solid pedestal base for the above is evidence of the increasingly professional use of such equipment (Fig. 5).

The incorporation of a removable 6-in. speaker into the side of the projector cabinet has permitted a weight reduction to 35½ lb for the Bell & Howell single case 185 projector. Bell & Howell also announced a new design of 2-in. $f/1.6$ Super Proval projection lens for all current 16-mm projectors. The lens resolves 100 lines/mm at the center, 80–90 at the side, and 40 at the corners. The design is a descendant of a Petzval incorporating a modified form of field flattener.

Except in special instances the Navy is producing no more official sound slide films for training purposes at the present time. The Filmagraph is being produced to take their place. In certain instances, it replaces regular motion pictures where motion is not an integral part of the teaching. The Filmagraph is a series of still pictures or art frames, either color or black-and-white, photographed on 16-mm film at 24 frames/sec. An appropriate sound track accompanies the picture, and it is projected on a regular 16-mm sound motion picture projector. The Filmagraph may include stock motion picture footage and simple art work. Its advantages are: (a) economy by standardization on one type of projection equipment, (b) elimination of synchronization difficulties often encountered with sound slide films, (c) better average projection conditions than for slide films, and (d) ease of handling and storage.

TELEVISION

Probably the most radical step in the changing scene in television production was the purchase of Vitagraph studio property in Hollywood by the American Broadcasting Co. These stages upon which some of the most famous motion picture stars performed before the cameras now give ABC Television Center facilities for operations comparatively unhindered in contrast to cramped quarters of the radio broadcast studio (Fig. 6). The site covers 23 acres and is said to contain the world's largest television sound stage. The facilities include process projection, permanent sets and some of the other

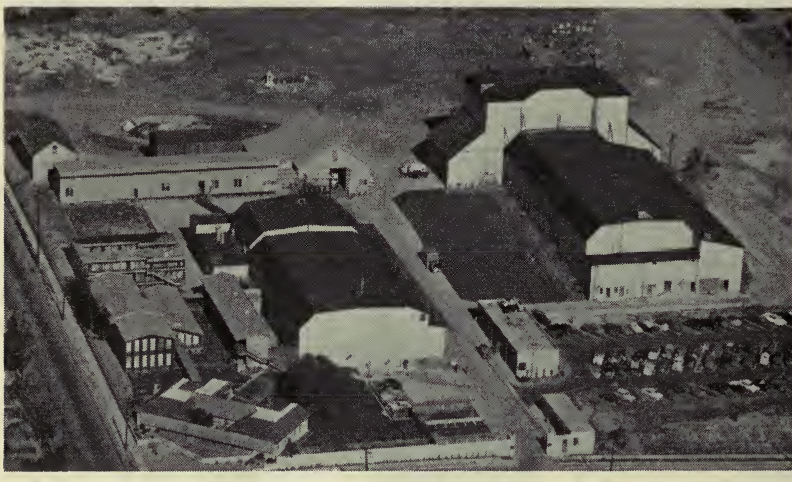

Fig. 6. ABC Television Center, Hollywood, Calif.

devices at least temporarily adapted from motion picture studio production techniques. Additional freedom in set lighting is appreciated by the motion picture cinematographers who are finding a place in the new medium.

The Navy is studying the effectiveness of television as a medium of mass training. The research is centered at the Special Devices Center, a field activity of the Office of Naval Research. Several experimental telecasts to classes assembled at Naval Stations have already taken place.

Use of Films in Television

During the past year the use of film programs on television expanded in volume and improved in tone quality. Several production

companies are regularly supplying program material as well as commercials for television usage that are specially prepared from script writing through laboratory processing of the composite prints. Efforts of this sort have led to the development of production techniques using several cameras operating simultaneously on a single scene and have permitted very rapid and relatively inexpensive production as well as dramatic techniques impossible in a television studio.

Some experiments have been conducted with a view to filming live television programs in the studio simultaneously with the over-the-air action, or during dress rehearsal. This might lead to the use of such films in place of video recordings.

In television studios background process projection is becoming more prevalent. The Holmes Projector Co. has developed a new machine for this purpose with a high efficiency shutter cycle.

Video Recording

The over-all quality of video recordings has improved considerably. More stable operations resulting from larger volume of recordings and improved original picture material are chiefly responsible. Specialized control devices for the recording operation and better liaison with motion picture laboratories rather than radical departure from previous methods have been the rule.

The widespread use of the Type 5820 image orthicon tube in the studio has provided better original material for the recordings which appears to be a very large factor in the results obtained. Reviews of video recordings have led to more emphasis on studio lighting which in turn has led to better recordings.

Producers' Service Co. has developed a 16-mm camera for video recording. This is of the mechanical shutter type. Preliminary experiments are being conducted in the recording of color television. Up to the present extremely large aperture lenses have been required.

Television Recording

The increased use of 16-mm sound recording by the television industry and the desire for improved sound quality have resulted in RCA's modification of 35-to-16-mm sound reduction printers for various domestic laboratories. The modified printers have lower flutter, double speed of operation and, in general, improved performance.

The high-frequency biased direct-positive variable density recording system mentioned in last year's Progress Report has been reduced to production practice in the recording of 16-mm films for television.

Theater Television

Considerable progress was made in 1949 toward establishing theater television as a regular commercial service.[41-44] However, one of the major problems, that of program distribution, remains unsettled. The cost of high-quality programming makes it desirable to link many theaters so that all can show the same program simultaneously and the cost per theater will be low. Two means of linkage are under consideration: (1) use a licensed common carrier now operating video distribution facilities, or (2) set up privately owned facilities. Because current carrier facilities are limited and rates are high, theater owners have been investigating the latter possibility.

Twentieth Century-Fox Film Corp. and Paramount Pictures, Inc., have experimented with micro-wave relays for linking theaters operating on experimental licenses granted by the Federal Communications Commission. Because of numerous requests from theaters for commercial licenses, the FCC requested that Twentieth Century-Fox, Paramount, and the Society of Motion Picture Engineers prepare answers to a series of specific questions relating to specifications and spectrum required for a nation-wide, competitive, series of theater television networks.

Along with the data submitted in answer to these questions, each group petitioned the FCC to hold public hearings on the allocation of frequencies for the sole use of theaters for program distribution. The Theatre Owners of America, Motion Picture Association of America, and many independent theater circuits submitted similar petitions. Other urgent business before the FCC has held up such a hearing but it is expected shortly.

Twentieth Century-Fox completely engineered a network of 24 theaters in a 400 sq mi area around Los Angeles, including program originating facilities and micro-wave distribution facilities. They have indicated that such a network could be in operation in a year after commercial licenses were granted.

The first production-type theater television equipment was sold in 1949. While RCA had already delivered a number of equipments to Twentieth Century-Fox, Warner Brothers and the Army Signal Corps, these were intended primarily for experimental use in evaluat-

ing and developing this new medium. During 1949, however, the first production RCA Direct Projection model was sold to Fabian Theatres Corp., for installation in the Fox Theatre in Brooklyn. A second unit was sold to American Theatres Corp., and installed in their Pilgrim Theatre in Boston. Paramount Pictures, Inc., has a permanent installation of their "Intermediate Film" equipment in the Paramount Theatre in New York and this year installed an equipment in their Chicago Theatre in Chicago.

Early in April, RCA first publicly demonstrated its new model "Direct Projection" equipment before the Society of Motion Picture Engineers. In this unit, the optical elements were reduced from the 500-lb, 42-in. spherical mirror and 21-in. glass corrector lens used in the early equipments to a 50-lb, 20-in. mirror and 15½-in. moulded plastic lens. The optical barrel, or projector, was separated from the control equipment so it could be installed in the auditorium at the correct projection distance from the screen and the controls could go in the projection room.

In June this equipment was installed at Fabian's Fox Theatre in Brooklyn to bring the Walcott-Charles heavyweight championship fight to an overflow crowd of spectators almost 1000 miles from the scene of the event. The fight was simultaneously shown at the Paramount Theatre using their "Intermediate-Film" equipment.

Both RCA and Paramount demonstrated their equipments to the Theatre Owners of America at their convention in Hollywood in September. Paramount's equipment featured a new high-speed drier which reduced the time between photography and projection to 20 sec.

At the Theatre Equipment and Supply Manufacturers' Convention in Chicago, RCA demonstrated its equipment to 2500 theater exhibitors and equipment manufacturers. The demonstration featured a professional middleweight fight staged in the NBC studios and sent by direct line to the projection equipment at the Stevens Hotel. This is the first time an official match was staged in a broadcast studio specifically for a theater-type audience at a remote location.

The 1949 Baseball World Series was shown to paying audiences in the Fox Theatre, Brooklyn, the Pilgrim Theatre, Boston, and the West Side Theatre, Scranton, by means of direct projection equipment. It was also shown in the State-Lake Theatre in Chicago by means of film recorded on Paramount's equipment in the Chicago

Theatre across the street. Two Milwaukee theaters showed the Series on 7 × 9 ft screens set up on their stages using smaller direct projection equipment.

The Pilgrim Theatre in Boston showed a series of three Notre Dame football games. The final game of the series was also shown in the Fox Theatre in Brooklyn.

The Fox Theatre in Brooklyn worked with the Board of Education in a public service experiment. On a week-day morning they opened their doors free to New York High School students and their teachers who witnessed a morning session of the United Nations.

In addition to the intermediate film storage method and the instantaneous method of television projection the Swiss eidophor system, which uses an auxiliary light source and is still in the development stage, offers a means of providing adequate screen illumination for large theaters.[45]

C. W. Handley, *Chairman*	G. H. Gordon	W. L. Tesch
J. E. Aiken	R. E. Lewis	J. W. Thatcher
L. W. Browder	W. A. Mueller	W. V. Wolfe

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The Shape of the Television Screen

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Summary—The standard aspect ratio of the television screen is four units of width to three of height. When the picture is originally scanned on the target of the image orthicon tube, it is a rectangle of this proportion. The pictures that are viewed by the public on many home receiver screens, however, bear little resemblance to the 3 by 4 rectangle, and greatly alter the framing and composition which the cameraman originally created. The fault is in the home receivers; films and live television pictures suffer equally in this regard. The general adoption of a rectangular tube will alleviate this problem somewhat, but a large share of the trouble arises from receivers which are improperly adjusted as to picture size.

The height, width and centering controls on a television receiver are usually adjusted only by a more or less competent serviceman, but on many sets they are not too well hidden, and the owner of the set may alter them from time to time. The result is that a certain proportion of sets are out of adjustment in regard to picture size. This maladjustment is usually made in the direction of overscanning of the receiver tube, since the results of underscanning are much more noticeable (Fig. 1).

Early in 1948, WABD in New York received so many complaints from clients who had failed to see their entire advertising messages on home receivers, that they set out to determine exactly how much loss was sustained by the average set. A test chart was transmitted (Fig. 2) with numbers at the edges reading in toward the center, and the audience was asked to report which numbers were visible. On the basis of 50 replies tentative conclusions were announced. These were stated in terms of marginal losses, but for the purposes of this discussion I have translated them into terms of picture area. The study was conducted by Otis Freeman, now assistant chief engineer at WPIX. These were the general findings:

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only 26% showed 94% or more of picture area;
31% showed 88% to 94%;
33% showed 81% to 88%;
6% showed 75% to 81%; and
3% showed 69% to 75%.

These very general figures are plotted in Fig. 3. This survey was made before the advent of the curve-sided and circular screens. All the receiver screens involved were roughly rectangular. The losses in picture area were due to improper picture-size adjustments of the receivers. There is no reason to believe that these same maladjustments do not still exist on most types of sets.*

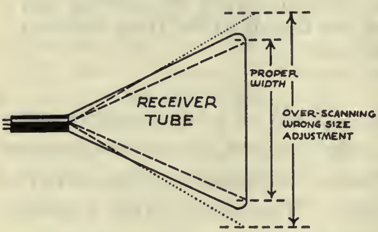

Fig. 1. When the height or width control on the receiver tube is set for too wide a sweep, the beam will strike the sides of the tube and only the center portion of the picture will be seen.

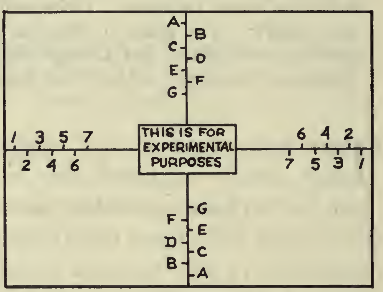

Fig. 2. Chart transmitted in WABD survey to determine loss of picture area.

A much more serious condition now exists in the circular screen. Even when height and width controls are in perfect adjustment on such sets, if the picture is to fill the screen, only 59% of the transmitted picture area can be seen (Fig. 4). Improper adjustment will increase this loss. Assuming that the same proportion of maladjusted receivers exists today, a survey similar to the above, based on 50 circular-screen sets would reveal tremendous losses of picture area. This has been calculated in a simple way: each of the values for per cent of picture area listed above has been applied against the 59% total possible picture area of the circular screen. Thus 94% of the picture

* The published results were as follows: "If there is an 8½% margin between the vital information and the top and bottom edge of the transmitted picture, at least 96% of the receivers will show this information vertically. Horizontally, if we leave a 13% margin between the vital information and the edges of the picture at least 95% of the receivers will show this information. With a 10% horizontal margin, 88% of the receivers will show it." Otis Freeman, *Television*, March, 1948.

area would become 94% of 59% of the picture area, or 55%. There are certain other factors involved, but the limited data available do not warrant any more detailed analysis. These figures are plotted in a curve (broken line) in Fig. 3.

The best-adjusted 26% would show 55% to 59% of picture area;
31% would show 52% to 55%;
33% would show 48% to 52%;
6% would show 44% to 48%; and
3% would show 41% to 44%.

Advertising claims would have the public believe that removing the mask and showing the entire face of the receiver tube (the "full-vision

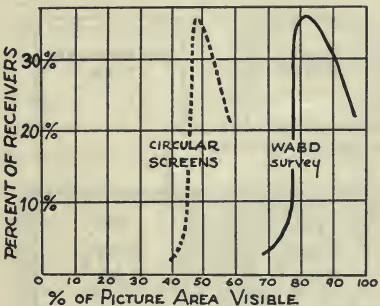

Fig. 3. Results on WABD survey calculated in terms of per cent of picture area visible. Broken line indicates possible results if a similar survey were conducted among the same number of circular-screen sets.

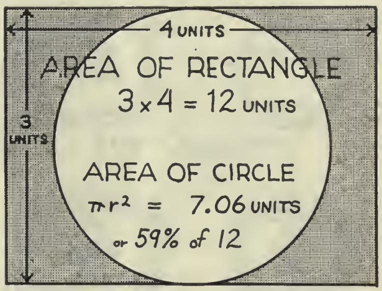

Fig. 4. Relation of area of 3 by 4 rectangle to area of circle. The circular area is only 59% of the size of the rectangle.

screen") somehow gives more picture, showing areas of the receiver tube on which all along there have been picture areas which the rectangular mask of the "ordinary" set has been cutting out. This is, of course, the reverse of the truth; removing the mask from the face of an "ordinary" receiver tube would simply reveal unused and dark areas. The broadcasting station sends a rectangular picture; it is rectangular from the moment it leaves the camera.

To fill a circular screen with this rectangular picture the set manufacturer must expand the height of the picture until it is equal to the diameter of the circle, and expand the width a proportional amount. The result is, of course, that figures appear much larger on the screen of a given size tube than they would if a rectangular mask were used.

The image of a wrestler, for example, may be 6 in. high on a 12½-in. receiver tube masked off for a rectangular picture (Fig. 5). When the mask is removed, however, and the picture expanded to fill the entire face of the circular tube, the image of the wrestler becomes more like 8 or 10 in. high—as large as it ordinarily would appear on an 18½-in. tube.

The close-up effect, however, carries no improvement in detail. The figure is still composed of the same number of picture elements; they are all enlarged together on the screen. The 6-in. image of the wrestler on the rectangular picture is scanned by 300 or 400 lines, possibly around 60 lines to the inch on the receiver screen. The 10-in. wrestler in the circular picture is composed of the same number

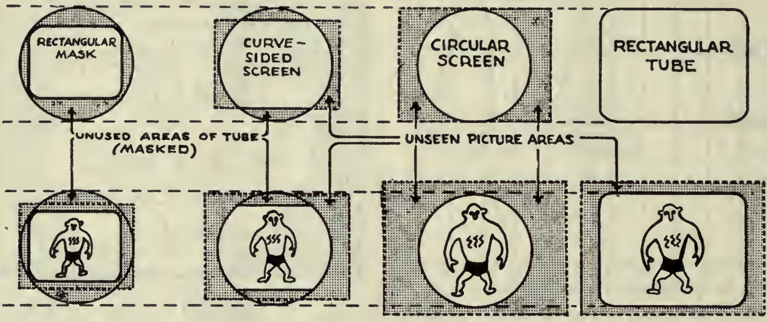

Fig. 5. Four methods of putting the rectangular television picture on the end of a cathode-ray tube. Each of these types of sets may be improperly adjusted and additional portions of the picture area may be lost, as indicated in the lower part of the figure.

of lines, but they are now spaced out to about 45 lines to the inch. Graininess appears worse from the same viewing distance.

The most serious handicap of this screen shape is the havoc it can play with picture information and carefully planned composition. A television sponsor on one of the New York stations advertised an item for 2.95 and was somewhat startled to see it come out for only .95 on a home receiver. This is loss of important information; other picture values suffer as greatly. Very few subjects which the camera can frame lend themselves to a satisfactory composition within a circular boundary. Pictures throughout history have nearly always been square or rectangular in shape. The predominant lines and planes in almost any scene are horizontal and vertical; the horizontal and vertical boundaries of the frame tie in with these and make unified and

pleasing compositions possible. It is only in the case of such things as miniature medallions or portraits from the horsehair sofa days that the public has been inclined to accept a circular picture. The subjects for these compositions were in the nature of Madonna groupings, and portraits, where curved lines which repeated the lines of the frame could predominate.

The broadcaster looks on the circular screen much as though he were a publisher putting out a magazine with the knowledge that a certain number of readers would, before reading it, take large shears, cut a circular piece out of the middle, and throw the rest away. He wonders to himself how long motion picture producers would stand for it if exhibitors insisted on running their pictures on circular screens. Many people in the industry throw up their hands in disgust and refuse to admit the existence of the circular screen at all. This point of view, however, is not shared by the advertiser, who must reach as many viewers as possible with his commercial message. Most manufacturers are planning to produce sets built exclusively around the new rectangular tubes. The saving in cabinet cost, a large item in set manufacture, is a primary concern. As soon as blanks of these tubes are available in sufficient quantity, practically all new sets will have screens of a rectangular shape. Until such time as the circular screen is obsolete, however, the broadcaster must make allowances.

Some cameramen prefer to set their view finders so they will overscan. By expanding height and width on the view finder tube the cameraman thus recreates the conditions of the average set. He takes a serious risk, however. His constant worry, the overhead microphone, although out of his frame entirely, might be painfully visible on well-adjusted sets.

Another solution which has been attempted is to overscan the target of the image orthicon tube. When this is done, the original picture includes border areas which would not ordinarily be scanned. The corners, at least, are not of broadcast quality, since they contain the images of the circular rim of the image orthicon photo-cathode. Assuming, however, that these distorted corners will be lost on all sets, this method has some value in that it permits the camera tube to be operated in a more efficient manner. Since the essential area of the picture (the portion which is visible on the average poorly adjusted receiver) is thus scanned from a larger area of the target plate, it is theoretically possible to put out a signal of better resolution.

However, no matter how large an area is originally scanned and

transmitted, the relative area of picture loss will be the same. The television production crew must constantly be reminded of the limited area of many home receiver screens.

CBS television has attacked the problem in a logical way. A celluloid sheet, outlined with an oval shape, is laid across every monitor and across the camera view finder screens as well. The cameramen call this the "elipse of essential information" (Fig. 6). It encompasses a little over half of the picture area. When a subject is considered absolutely essential (such as part of a commercial message or an object of importance to the plot), it must be kept within that area.

The producer of film for television use is vitally concerned with this problem of picture loss. Some television film cameramen are using special view-finder masks which cut out a certain portion of the picture area and insure a composition that will not lose anything essential on a poorly adjusted receiver.

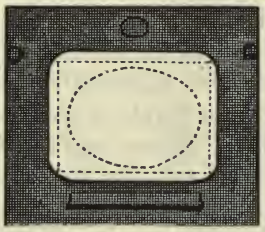

Fig. 6. CBS monitor overlay, indicating areas of picture loss.

Graphic artists and photographers have often had a better opportunity to work closely with television stations in the preparation of slides and title cards, and several formulas have been developed for establishing the safe and usable area.

For the sake of the discussion that follows, I have chosen to call this the "essential area." The total area which the camera will pick up, or which will be projected on the mosaic of an iconoscope tube, I have called the "picture area." The border area within, which when added to the essential area makes the picture area, may be called the "supplementary area." Information supplementary but not essential to the picture may be included in this region.

Compared below are three formulas which have been worked out for establishing these areas. The first, and I believe the easiest for the artist to use, was developed by Ray Sherwin when he was art director at Young and Rubicam (Fig. 7).

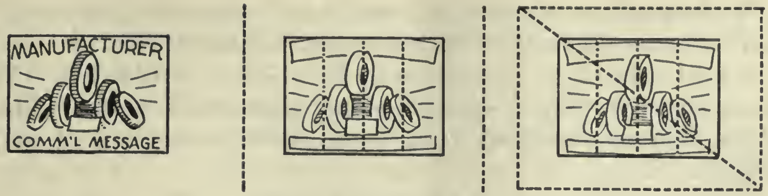

Fig. 7. Sherwin Method.

A. Start with the picture as it should appear on a poorly adjusted home receiver. This is the essential area.

B. Divide it into quarter sections vertically.

C. Add a border one quarter the width of the essential area on either side.

D. Run a diagonal through the corners of the essential area to locate the corners of the picture area.

E. Add top and bottom edges to the picture area.

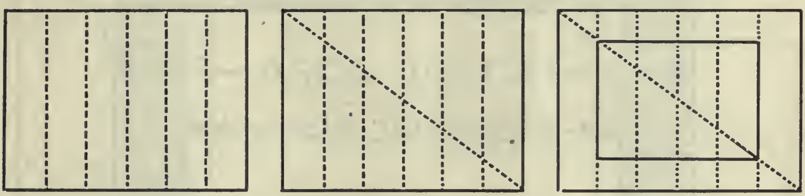

Fig. 8. Sherwin Method, reverse.

A. Lay out a picture area on the card. (The artist may prefer to allow a small margin around this to keep finger prints and edge damage out of the picture area.)

B. Divide it into six equal vertical sections.

C. Run a diagonal through the corners. The points where the diagonal intersects the first and the last dividing lines establish the corners of the essential area.

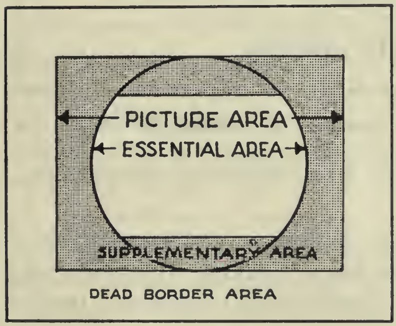

Fig. 9. WSYR-TV Method.

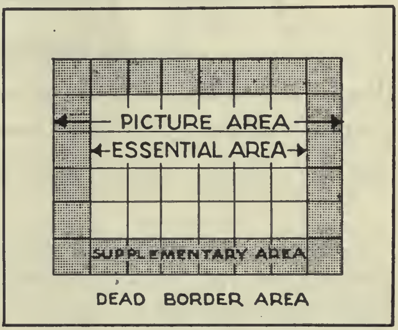

Fig. 10. WJZ-TV Method.

A. Starting with the $3\frac{1}{4} \times 4$ in. card, first mask off a $\frac{1}{2}$-in. dead border area. This leaves a picture area of $2\frac{1}{4} \times 3$ in. which is the standard picture area for lantern slides of this size.

B. Then draw a circle as large as possible within this area.

C. Draw horizontals across the circle $\frac{3}{8}$ in. in from the top and bottom of the picture area. This is the essential area.

Working in reverse, one may instead want to start with a blank card and determine the limits of the essential area within it (Fig. 8).

A good method was worked out by Bert Gold at WSYR-TV. This was used for the $3\frac{1}{4} \times 4$ in. slides and opaque cards on which that station had standardized, but it is adaptable for any size of work (Fig. 9).

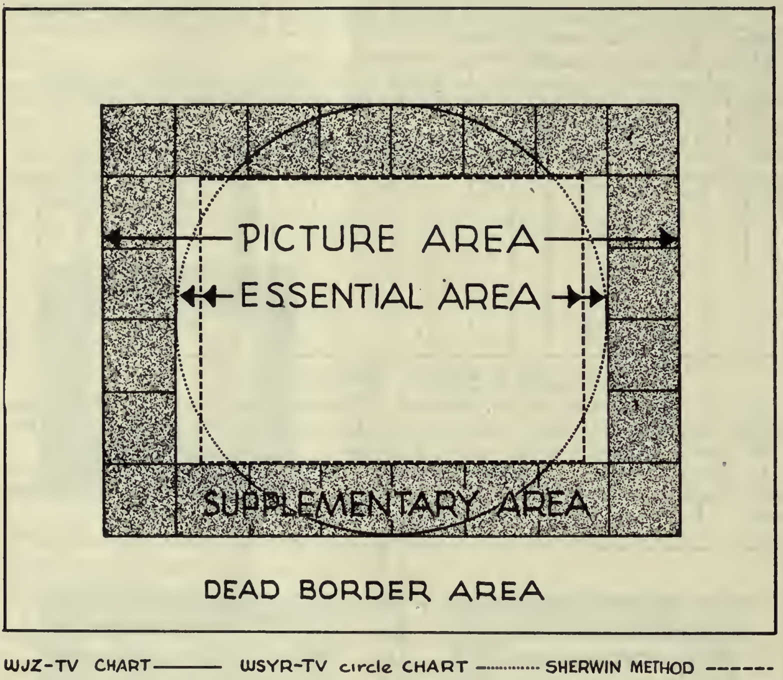

Fig. 11. Composite chart of three methods of establishing essential area.

The Gold method has one thing in its favor: the curved sides of the essential area probably make this closer to average receiver-screen shape and discourage the use of the corners where information is most often lost or distorted.

A third method is one which was devised some time earlier at WJZ-TV as a guide in the preparation of 2×2 in. slides. The picture area is divided into 48 squares (Fig. 10). The supplementary area is established as a border one square wide around the edges of the picture area. This comes to just exactly half of the picture area.

However, the essential area which is established by this method is wider than the standard 3 by 4 aspect ratio and might prove inaccurate at the sides.

All three of these formulas for establishing the essential area pretty well agree on its size, although proportions may vary somewhat (Fig. 11). In each case the essential area is roughly half of the picture area. This is a severe limitation, but one that is probably only temporary. As the proportion of sets built around the rectangular tube grows larger we can expect gradually to increase the size of the essential area.

In summary, here is a list of the unpredictable factors which determine the visible portion of a televised picture:

1. *Transmission*
   a. Studio cards: The framing of the camera may be hasty and inaccurate.
   b. Slides and film: The projector may be set up so that the projected image will exceed the area of the iconoscope mosaic.
2. *Reception*
   a. The receiver screen may be of some strange shape, with curved sides, or circular.
   b. The width, height and centering controls on the receiver may be improperly adjusted.
   c. In some receivers there may be distortions near the edges which would make lettering illegible.

The coming of the rectangular tube is a boon to the entire television industry, but the problem will not be entirely solved until some way is found for keeping home receivers properly adjusted for picture size. Perhaps an educational campaign on the part of the broadcasting stations is indicated. If a simple chart or picture were transmitted with the announcement that "if the entire design is not visible your set is out of adjustment," servicemen might find themselves obliged to adjust more sets properly. In any event the industry could well use further surveys, along the lines of Otis Freeman's study, to determine from time to time just how serious is this problem of the shape of the television screen.

Picture-Synchronous Magnetic Tape Recording

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The D. G. C. Hare Co., New Canaan, Conn.

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Summary—Quarter-inch magnetic tape offers considerable economic and operational advantages for the recording of sound track material. The theory and basic design of a system which provides completely adequate synchronization of the sound with the picture are discussed. Various methods of automatically framing the sound track and picture are considered, and a simple system capable of rapid framing is described.

Because it eliminates the need for careful control both during recording and processing and particularly since it allows immediate playback of a recorded track, the use of magnetically coated film stock has been the subject of considerable interest and investigation during the past two or three years. In addition, the use of such a recording medium results in a considerable saving since the stock can be erased and re-recorded a good many times. However, the problem of achieving good motion with sprocketed stock has not become easier but, on the contrary, has been to a certain extent increased, since in magnetic recording we need to maintain intimate and very constant contact between the magnetic material on the film and the surfaces of the record and playback heads. This is not always easy to do and the difficulty increases with the stiffness of the stock.

With the much thinner standard quarter-inch magnetic tape the problem of achieving really good motion is not difficult and, in addition, this tape costs from eight to ten times less than an equivalent footage of sprocketed stock. These two considerations have led, during the past year, to the development of several systems of synchronizing this unsprocketed tape with a projector. We would like to describe the system which was developed for the Fairchild Recording Equipment Corp. and which is incorporated in their Model 100-B Pic-Sync Recorder (Fig. 1).

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We may state the problem quite simply. What is desired is to play back a sound track from a tape recorder with a speed regulation such that over at least a half hour the maximum time or displacement error of the tape with respect to the film is something less than one frame.

Driving the tape recorder capstan synchronously is not enough, since even though the slippage or creep of the tape around the capstan can be minimized to nearly any desired degree, the tape, whether it be

Fig. 1. Model 100-B Pic-Sync Recorder.

made with a paper backing or with a plastic base, is subject to stretch and contraction as a result of mechanical strains, as a result of temperature changes, and perhaps more important than either of these, as a result of humidity changes. Sprocketed film suffers from all these ills too, but in this case we never accumulate the bad results for more than a frame, always supposing, of course, that whatever stretch or contraction occurs is not so much that the sprockets cannot engage

their proper holes. In tape, however, we can have cumulative effects. For example, if a piece of film stretches 1% we would be out at most 1% of a frame. With a half-hour roll of tape, this 1% stretch would amount to some 18 sec or about 430 frames. To maintain one-frame accuracy in a half hour requires a cumulative speed control of the tape over this period of time of one part in something more than 40,000. Looked at this way, the problem seems a rather hopelessly formidable one. Actually, the solution is simple and, based upon the results of several hundred hours of commercial television operation, completely reliable.

There are several different approaches to the problem, all based upon the principle of putting on the tape during manufacture or at the time of recording, a mark—either physical or magnetic. the spacing of which will change with the stretching and contracting of the tape at exactly the same rate as does the program material which has been recorded. There are quite a few ways of doing this. One may make use, as has been done, of tape which during its manufacture has had marks placed on the back; one may, as has been very ingeniously done, make use of a control track which is recorded at right angles to the program track; one may record a subharmonic of the line frequency below the audible range, or the line frequency itself, or a harmonic of it in the audible range, and later chop it out; or one may record, as we have done, a control track as the modulation of a carrier which is placed at the extreme end of the high-frequency spectrum, say at something above 14 kc (kilocycles per second) and limit the playback response of the program channel to a kilocycle or so below this. In all cases, for reasons that will appear later, it is desirable from the standpoint of simplification that the control signals bear an integral relationship to the line frequency at the time of the recording. Obviously each system has a reason for its choice of control and the following is somewhat the way our reasoning went.

The printed tape requires two things: first, a special tape; and second, a photocell or other device for scanning the tape, which means additional components in the tape transport-pickup system. The system of recording a track at right angles to the program track requires both on recording and playback either an additional head or a special head. The subaudible signal, unless it is put on at a very low level, will usually result in hum components due to distortion products, and nearly always requires a modification of the record and playback channels since most recorders cut off somewhat above 30 cps (cycles per second). Further, it is generally true that both the

signal handling capacity and signal-to-noise ratio of most tape recorders is poor in the extreme low range.

In using a high-frequency carrier we, of course, pay the price of moderately limiting the high-frequency response, but since the resulting 13-kc upper limit is still not only well above the usable upper frequency range of most film systems, but also is above the reproducing range of most of the reproducing systems used in conjunction with the film, this is not a serious consideration.

Most professional recorders running at 15 in./sec have a guaranteed response of 15 kc, and by using this system we can record a control track on any tape recorder with only the addition of a simple bridging unit which is placed in the program channel just before the tape recorder. The tape can then be played back in synchronism with the film on any Pic-Sync recorder. This allows the user to record a sound track on available equipment, a consideration we believe to be quite important.

Having marked the tape either physically or by means of a control signal, our next question is the method of applying the control.

Since we have two units, the projector and the recorder, we can control either of them. We do not believe, for several reasons, that the control of the projector speed would result in the best practical system, and thus all of the following comments will refer only to methods of controlling the speed of the tape recorder.

If both the camera and the projector are driven by synchronous motors, they will move equal numbers of frames in equal time intervals if the time interval is measured in terms of the line frequency (as by a synchronous clock). On the tape recorder this means that in such an interval of time it must play back exactly the same amount of sound as was recorded, again remembering that the time interval is measured *in terms of the line frequency.*

As was mentioned before, the obvious thing to do is to use as a control track the line frequency or some multiple of it. If we do this, and on playback require that the difference between this control track frequency and the line frequency be zero at all times, we will have achieved our purpose. This is nothing more than a familiar servo regulator system. Of course, we cannot make use of the naive principle of merely amplifying the control track and causing it to drive a synchronous motor, since there is nothing in this system that tells us the difference between 59, 60 and 61 cps.

Perhaps the next obvious approach consists of recovering the control frequency and comparing it with the line frequency and using this

difference frequency to control the recorder speed. For example, let us suppose the line frequency at the time of recording was 60 cps and that this frequency was recorded on the tape as a control track. Further, let us suppose that between the time of record and playback the tape had stretched, so that if the recorder drove the tape at the same speed as it did at the time of recording, the control signal would be played back as 59 cps. For our comparison signal we might double the playback line frequency, which would be 120 cps, and obtain the difference between this and 59 cps from the tape. This difference frequency would be 61 cps, and if this frequency were used to control the speed of a synchronous motor, the tape would be driven faster than it was at recording, and at first glance one would assume that the 59 cps would come off as 60 cps thus correcting for the tape stretch. However, the difference frequency between 60 and 120 cps is 60 cps, which would give us 59 cps which, so to speak, is where we came in.

It is obvious that such a simple system as this will result in reducing the error by only a factor of two. If we use a higher multiple of the line frequency we could reduce the error in direct proportion to the multiplying factor. It is quite apparent that to make a correction to an accuracy of one part in 40,000 this simple method is impractical.

The problem of getting an error correction without having an error is a familiar one to those who work with servo mechanisms and the solution is basically quite a simple one. What one does is to examine the residual error over a period of time and *correct* the *correction* in accordance with this residual. This is what is familiarly known as "integral control." In our case it merely means that we want the time integral, over some period, of the difference between the line frequency and the control track frequency to be zero or, more exactly, that it not change with time. That is,

$$\int_0^T (f_l - f_c)dt \neq f(t) \tag{1}$$

where f_l = line frequency at playback,
f_c = control track frequency at playback,
T = time limit of integration, and
t = time.

There are several ways of achieving this result. The one chosen, we think, represents a fairly simple approach. It is based upon the fact that by definition frequency is equal to the rate of change of phase. Using this definition the above equation becomes

$$\int_0^T \left(\frac{d\varphi_l}{dt} - \frac{d\varphi_c}{dt}\right) dt \equiv \varphi_l - \varphi_t \neq f(t) \qquad (2)$$

where φ_l = phase of line current or voltage, and
φ_c = phase of control track current or voltage.

If we then use a control based on phase relationships rather than on frequencies we automatically achieve the desired integral control.

In its simplest form such a system of control is one in which the necessary speed correction is determined by the phase relationship between the control track frequency and the line frequency. If the system is such that all the corrections can be achieved during some part of a single cycle, then regardless of playback time we will never have a time error greater than the period of a full cycle of the line frequency. Figure 2 shows a block diagram of such a phase control system. The control track recording system is shown in the upper part of the figure and is completely straightforward. It consists merely of a 14-kc oscillator modulated with the line frequency, a high-pass filter to remove the line frequency, a volume control, and a bridging resistance which is connected directly to the record head. As mentioned before, this control track frequency can also be bridged in ahead of the recording amplifier permitting control track recording on any 15-in./sec tape recorder.

In playback we amplify the control track signal along with the program in the first two stages of the playback amplifier. In the Model 100 Fairchild recorder a playback volume control is placed in the front panel which makes for convenience in separating the control signal and the program. This is done by means of a rejection filter tuned to 14 kc and placed in series with the line to the pad. Ahead of this rejection filter the control track frequency is bridged out through a tuned network, after which it is amplified, further filtered, demodulated and limited. Following this limiting it goes to a power amplifier which feeds one phase of a two-phase servo motor at a level of about 15 w. On this phase, then, we have the control signal which was originally the line frequency at the time of recording. The other phase of this motor is supplied directly from the line. Figure 3 shows the phase-torque curve of this type of motor, the phase indicated, of course, referring to the relative phases between the two windings, and the curve shown being for a single motor speed. For any other speed we get a similar type of curve except that the maximum torque will be larger or smaller.

A simple example may help to visualize the way in which this phase-

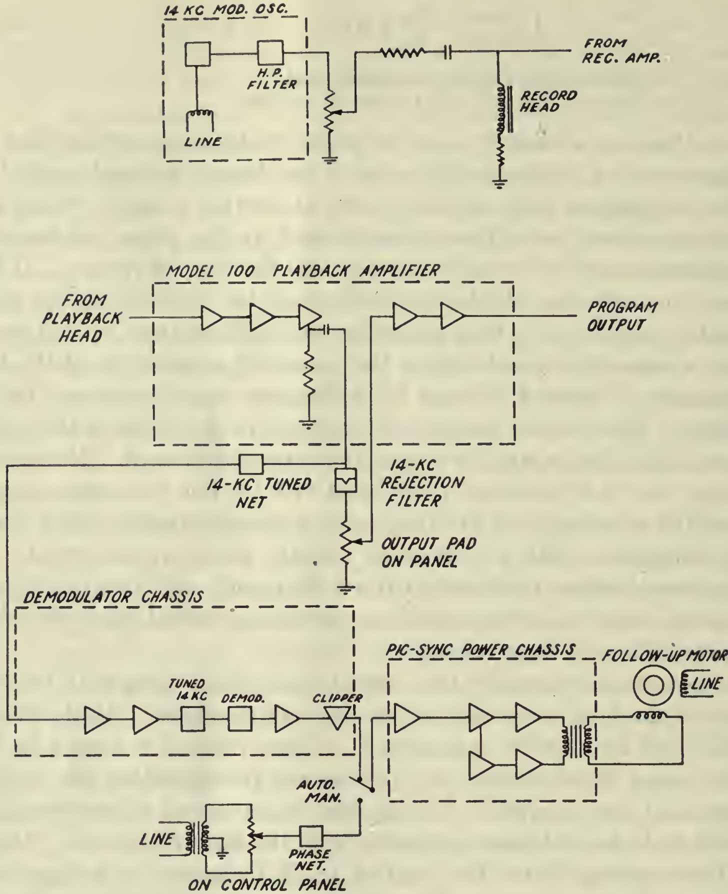

Fig. 2. Block diagram of phase control system.

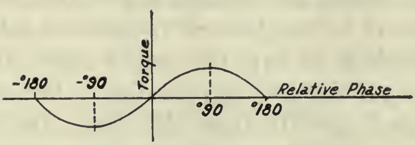

Fig. 3. Phase-torque curve for two-phase servo motor.

torque characteristic can be used to obtain the required speed control. Let us suppose, for example, that the frequency coming off the tape without any correction is very close to the line frequency—perhaps 59.8 cps. On the two phases of the servo motor we have, thus, two slightly dissimilar frequencies, and, hence, the phases of the

currents in the two windings are slowly varying with respect to each other. This, of course, means that the torque will also be slowly varying, going from zero to a maximum in one direction and back to zero and to a maximum in the other direction.

Now, if the motor is connected into the system in such a fashion as to reduce the tendency of the phase to change, it may be seen that under suitable conditions the speed will change to a value such that there is a constant phase difference between the currents in the two windings. That is,

$$\varphi_1 - \varphi_0 = \text{const} \neq f(t \tag{3}$$

Recalling equations (1) and (2) this is just the condition that is needed for our control.

This phase control method can be applied to a recorder-projector system in several ways. We can control the speed of the projector, the speed of the tape recorder main drive motor, the position or setting of a speed changer in the tape recorder, or we can "rate" the main tape recorder drive system. This latter method is the one used in the Pic-Sync recorder and is a broad application of the basic Synchroll principle which is used in the normal drive of this recorder. Since the details of this type of drive have not been published, it might be in order, for the benefit of those not familiar with it, briefly to digress for the explanation of its principles.

The development of the Synchroll was predicated upon the reasoning that in a sound system we require the drive to perform two entirely different functions. First, it must provide, over rather short intervals of time, extremely constant speed. Second, the playback time of the recorded program must, to a very high degree of accuracy, equal the time of recording over, say, a half-hour interval. In the past, most drive systems have tried to achieve these two somewhat dissimilar objectives with a single means or, more frequently, have ignored one in favor of the other. For example, the puck or friction roll drive when properly constructed is capable of having very precise short-term speed control, but all puck or other friction drives either slip or creep to a greater or lesser degree; and what is worse, this slip or creep may be, and all too frequently is, quite variable. The same remarks, of course, apply to belt drives. Gear drives, on the other hand, if the main drive is synchronous, will provide an absolutely synchronous drive system, but the difficulties of getting the tooth ripple out of the gear drive are all too well known to anybody who has tried it. We can, of course, eliminate this gear ripple if we use a

sufficiently soft coupling, but as soon as we do this we have a system which is also soft, and which not only takes a long time to settle down but which when disturbed by a sudden change of load will give rise to a very disturbing wow.

The elements of the drive are shown in Fig. 4. Disregarding the right-hand motor for the moment, we have on the upper end of the motor shaft a conventional puck drive. The bottom of the motor shaft is coupled to a gear train which, in turn, is coupled to the flywheel shaft. Both the motor and flywheel shafts are isolated from the gear train with soft couplings. If, for the moment, we consider the puck drive separately, we have a drive system which has a characteristic rigidity or stiffness but which, in common with all friction drives,

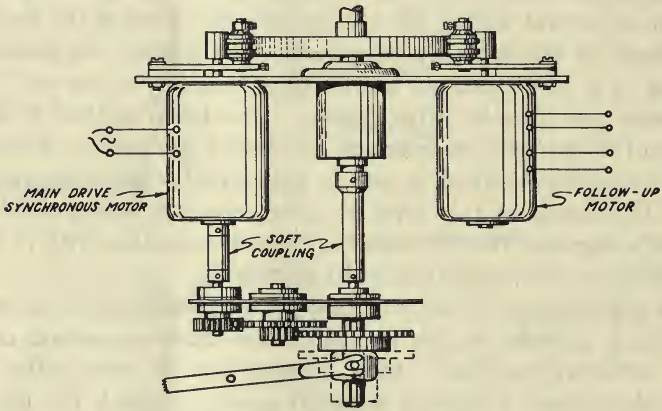

Fig. 4. Elements of the drive.

tends to slip or creep. Figure 5 shows a typical speed-torque curve for such a drive. We deliberately chose the diameters of the motor pulley and the flywheel such that their arithmetical ratio is a percent or two lower than that of the gear train. Thus if the puck did not slip it would drive the capstan a percent or two faster than would the gears. The gears coupled to the capstan through the flexible shaft can then be considered as a load which causes the puck to slip just this percentage. Figure 5, for example, shows that a load of 25 inch-ounces would be required to reduce the speed from 225 rpm to 218 rpm. The soft couplings between the gear drive and the motor and capstan effectively filter out any gear ripple, while the stiff coupling of the puck effectively eliminates the hunt and softness due to this flexible coupling.

This type of drive can be looked at in two ways. It can either be considered as a puck drive with a follow-up or rating system which keeps it synchronous, or it can be considered as a gear drive with a very high amount of damping supplied by the puck.

For the Pic-Sync operation we consider the drive from the first of these two viewpoints. In this operation the gear drive is disengaged although the main motor is still coupled to the flywheel through the puck. The follow-up motor, which is the servo motor shown in the block diagram, whose speed or torque is proportional to the relative phase between the line and the control signal, is also coupled to this flywheel through a puck. The phase-torque characteristic of this motor then provides a varying load on the main drive motor, in some cases assisting and in others retarding. Since this is what is commonly known as a "closed loop" system, there is no need for a gear coupling

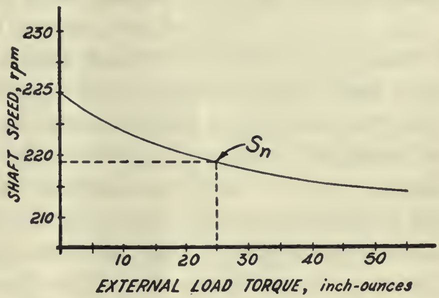

Fig. 5. Typical speed-torque curve for the drive.

to the capstan. As previously explained, as the tape comes up to speed, the control signal appears on one winding of the follow-up motor, and the phase of the current in this winding will be varying slowly with respect to that of the line phase. The system is so connected that as the phase varies, the torque of the follow-up motor changes the speed of the tape in such a fashion as to oppose the change in phase. Given enough power the follow-up motor will hold the speed at a point such that the frequency of the control signal is equal to that of the line frequency. At this point the phases of the currents in the two windings are such as to provide just the torque necessary to load the main drive puck system to this proper speed. This is a stable operating condition, and since the control track frequency and the line frequency are now the same, we are playing back our program at a rate which referred to the line frequency is exactly that at which it was recorded. If the projector is driven by a synchronous motor, the program on the tape will be in exact synchronism with the picture.

If the system is tight enough, that is, if the follow-up motor has adequate power, all corrections will be made with a phase change of not more than ± 180 degrees, so that no matter how long the playback time, the error between the tape and projector will never be more than the period of a single cycle of the line frequency. This, of course, assumes a damped steady state response. A very satisfactory aspect of this type of rating system is that, just as in the case of the standard Synchroll drive, the main drive motor and its puck coupling provide a tremendous amount of "built-in" damping for our rating mechanism.

At the lower left of Fig. 2 is shown an additional input to the Pic-Sync power amplifier. This allows the control phase of the motor to be fed directly from the line in such a way as manually to adjust the speed of the recorder. This is normally not used in Pic-Sync operation but is introduced merely as a convenience for the purpose of changing the time of playing back an uncontrolled program. It could, of course, be used for a manual framing device if desired.

The question of the effect of splices is frequently raised. Naturally, if the tape is properly spliced before recording, the splice has no effect. If the tape is cut and spliced after recording, as in editing, we will probably cut out something other than an integral number of 60-cycle control waves. When the splicing passes the playback head, there will then be an abrupt change in the relative phases of the line and control frequencies. The transient response of this system is such that there is practically no audible effect from this abrupt change and the damping is sufficient so that there is no tendency to hunt, the follow-up motor merely taking a new position of equilibrium. In so doing it may pull ahead a half cycle or fall behind a half cycle. The expected accumulated error from a number of splices is a probability function which depends upon the constants of the system and which is not easily calculable. Our experience has shown that on the average the error due to random splicing is a good deal less than a quarter of a frame per splice. Since at 15 in./sec the wavelength of a 60-cycle signal is approximately one-quarter inch, it is a relatively easy job to make a good approximation to ideal full-wave splicing if such precision should ever be required.

Performance tests of the over-all system accuracy have repeatedly shown an accumulated error of less than one-quarter frame in a half hour. These tests were necessarily laboratory ones and do not mean very much in terms of commercial operation. We believe that perhaps the best evidence of the stability of this control system is that

two machines which have been in daily use at WCBS-TV have an operating time of well over one thousand hours and have been used many times to provide the sound track for telecast programs.

There are two primary uses of a Pic-Sync recorder. One is to provide a sound track which is later dubbed onto film and eventually printed as a standard optical track on the picture stock. There are obvious economic advantages to using tape for this purpose. First, it permits immediate playback of the sound track without the necessity of the controlled processing of the optical track. Second, the cheapness and re-usability of tape make it economically practicable to record a large number of tracks simultaneously if desired, from which the master track can be mixed. Third, again as a result of its cheapness and re-usability, it is coming into increasing use as a safety track in conjunction with standard film recording. These, of course, are only a few of the uses of synchronous tape recording as an intermediate step to a final optical track.

The other major field for picture-synchronous tape recording is in its direct use as a sound track for projected material. In order to use the tape in this fashion one must have a simple and reliable method of bringing the sound and picture into exact frame synchronism at the start of the program. Since the projector and recorder are normally driven separately, this requires that the initial speed and movement of the medium on one be controlled with relation to these factors on the other.

There are two approaches to this problem. One of them consists in putting on the tape and film leaders a series of marks which bear some fixed relationship to the number of frames, and with the use of some monitoring method, properly adjusting the speed of the recorder and projector. This can be done visually, aurally or automatically, and in a proper system will result in exact framing at the start of the program.

The other method is based on the assumption that during the time it takes a normal five- or ten-second leader to be played, the effects of tape stretch, contraction, and even slip, are completely negligible. This we believe to be true for all high-quality tape recorders. Then one method, and a simple one, of bringing sound and picture into frame is merely to determine the relative starting times of the recorder and projector and either cut the leader to compensate for any difference or to start one or the other with the proper delay. This can and has been done with completely satisfactory results, but it

requires an individual and very precise adjustment for each recorder and projector and, much more important, requires that the relative starting times remain constant from day to day and temperature to temperature. This requirement is seldom if ever closely approximated.

Another of the unmarked leader methods eliminates these latter difficulties. It involves the comparison of the projector sprocket rotation with the capstan rotation of the tape recorder. In this system, the information regarding the sprocket rotation is transmitted to the tape recorder by means of a pair of very small self-synchronous (Selsyn) motors, one of which is fastened to the sprocket of the projector, and the other to one side of a differential in the tape recorder. The other side of this differential is connected, through a gear train of proper ratio, to the capstan drive shaft. The output of this differential then will be a measure of the difference of rotation between the capstan and the projector drive sprocket. If we choose the gear ratio such that one revolution of the capstan corresponds to the same number of frames of program material as does one revolution of the drive sprocket, the output shaft of the differential will remain stationary for synchronous operation. Any rotation of this output shaft is an indication of a framing error and we cause it to correct the speed of the recorder in such a direction as to reduce this error to zero. By suitable and rather simple means it is possible to store rather large framing errors and to correct these errors rapidly to a small fraction of a frame. For example, the recorder and projector will, if started at the same time, be out of frame by something between three and ten frames at the end of the leader. This error can be corrected, to a quarter of a frame within a matter of two to four seconds.

Inasmuch as this article is a transcript of the rather informal presentation at the meeting, no detailed discussion of the construction of this framing device is included. It is, however, worth while to point out that the device is arranged so that when the framing error has been corrected and the control track takes over the control of the speed of the tape recorder, the error-storing mechanism is disengaged from the differential and not re-engaged until the machine is turned off. This eliminates the necessity of manually resetting to zero at the start of a new program and it also makes it possible, when using tape that has been recorded under suitable conditions, to start and stop the projector several times during the program with a negligible framing error.

The Open-Air Concentrated-Arc Lamp

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Summary—**The open-air concentrated-arc lamp is a new form of the concentrated arc which operates in the open air and does not require any enclosing bulb or protective atmosphere. The light source is a sharply defined, circular spot which is formed on the end of the electrode by a thin film of incandescent molten zirconium. The lamps can be operated from alternating or direct current and can be made in sizes up to several kilowatts. A 1-kw lamp operating on alternating current draws 18 amp at 55 v and produces 3000 candlepower from a spot 5.4 mm in diameter whose average brightness is 130 c/sq mm. The radiation has a continuous black-body type of spectral distribution and a constant color temperature of 3600 K. Due to a unique operating principle whereby the zirconium metal is constantly renewed from its own products of combustion, the lamps can have lives of several hundred hours. The exhaust products are nontoxic and the electrodes are replaceable. The lamp is characterized by extreme stability and ease of operation. It is expected to find application in projection, television, flood and spot lighting and other fields which require intense light sources.**

The Western Union Open-Air Concentrated-Arc Lamp is, as its name implies, a concentrated-arc lamp[1] which operates in the open air without an enclosing bulb or protective atmosphere. While this new lamp is fundamentally a concentrated arc, in that the source of the light is a thin film of molten metal, its characteristics are quite different from those of the earlier types. Chief among these differences are open-air operation, an increase in operating voltage from 20 to 55 v, operation from either direct or alternating current and an increase in brightness from 50 to 130 c/sq mm (candles per square millimeter). An outstanding characteristic is its stability or steadiness of operation.

The theory of the new lamp can be best explained by a review of the

[1] W. D. Buckingham and C. R. Deibert, "Characteristics and applications of concentrated-arc lamps," *Jour. SMPE*, vol. 47, pp. 376–399; November, 1946.

Ibid., "The concentrated-arc lamp as a source of modulated radiation," *Jour. SMPE*, vol. 48, pp. 324–342; April, 1947.

Presented: October 14, 1949, at the SMPE Convention in Hollywood.

operation of the original concentrated-arc lamp. In the older type of lamp, the cathode, or negative electrode, consists of a tube of tantalum, or some other metal with a very high melting point, which is filled with zirconium oxide, ZrO_2. The positive electrode, or anode, is a simple metal plate with sufficient radiating surface to limit its temperature to a dull red heat during operation. After the enclosing bulb has been evacuated and filled with argon gas, the cathode is activated or formed. In this process a d-c arc is established between the anode and the metallic side wall of the cathode tube. The cathode tube soon becomes hot and heats the zirconium oxide within to a temperature at which the oxide becomes electrically conductive. At ordinary temperatures, zirconium oxide is an excellent insulator. The arc then strikes from the anode to the oxide and, under the intense ionic bombardment of the arc, the surface layer of the zirconium oxide is reduced to its two components, zirconium and oxygen. Thus, a thin film of zirconium metal is formed on the end of the cathode. During operation of the lamp, the metallic film is maintained in a molten state by the heat of the arc. This pool of molten metal is the chief source of the visible radiation from the lamp. Having been once formed during manufacture, the film of zirconium metal remains on the cathode so that on subsequent starts the arc establishes between the anode and the zirconium directly.

Even though the zirconium is maintained in a molten state during operation of the lamp, there is but little loss by evaporation for, as the zirconium leaves the surface of the electrode, it becomes ionized and is drawn back to the cathode. Any zirconium which does escape from the cathode is replaced by reduction of the underlying oxide.

These processes result in an excellent lamp with a life which may reach 1000 hr. The light source is a sharply defined luminous circular spot which is fixed in position and uniformly brilliant with an average brightness of about 50 c/sq mm. Thousands of them have been manufactured and they have found application in hundreds of different fields.

The investigation which resulted in the development of the open-air lamp started from the observation that the brightness of the concentrated-arc lamp drops sharply during the first few minutes following the initial forming operation. By the end of the first hour of burning the brightness has stabilized at or near 50 c/sq mm, which value is less than one-half of its initial brightness.

This decrease in brightness and light output was thought to be due

to a thickening of the zirconium-metal film which forms on the surface of the cathode. When first formed, the film is microscopically thin so that it can conduct but little heat from its molten center to the metal side walls of the cathode tube. With continued operation, however, more zirconium metal is produced. The film becomes gradually thicker and conducts more heat from the incandescent spot; and the brightness drops.

If all of the oxygen, which is released by the reduction of the oxide, remained free within the bulb, a state of equilibrium would soon be reached in which the number of molecules of zirconium oxide being broken into its components by the action of the arc would be exactly balanced by the atoms of zirconium and oxygen which were recombining to form zirconium oxide and the zirconium-metal film would remain very thin. In the ordinary concentrated-arc lamps, however, some of the oxygen combines with the hot molybdenum of the anode to form a molybdenum oxide. This oxygen, having been captured by the anode, cannot return to the cathode, so the zirconium-metal film gradually thickens.

As a test of this theory, a few lamps were constructed in which all of the metal parts, which become hot during the lamp operation, were made of platinum, a metal which does not readily combine with oxygen even when it is white hot. When tested, these lamps did maintain their initial brightness.

It appeared that a new line of high-efficiency concentrated-arc lamps could be developed by using nonoxidizing material for the metal parts of the electrodes. Platinum could be used but it is very expensive. The small amount used in a 25-w lamp would cost $20; and for larger lamps, the cost increased sharply. A search was begun for relatively cheap nonoxidizing electrode material.

This work was interrupted by an experiment made with the lamps with platinum electrodes. Since platinum would not burn in the oxygen-argon mixture which filled the bulbs of these experimental lamps, it seemed reasonable to suppose that they could be operated in the open air without any enclosing bulb. This was found to be the case. The lamps operated at an average brightness of 130 c/sq mm. Part of the increase in brightness of the open-air lamps is due to the thinness of the zirconium-metal film and part is due to the energy released by the zirconium in recombining with the oxygen.

The voltage drop across the lamps was about 55 v. This figure compares with 20 v for the concentrated-arc lamp operating in argon.

This is a considerable advantage for it is much cheaper normally, to supply a 1000-w lamp with 18 amp at 55 v than with 50 amp at 20 v, as is required by the argon-filled lamp. It was found also that the lamps could be operated on alternating current if they were made with two similar zirconium oxide-packed cathode-type electrodes. This too, is of great advantage for alternating current is usually available and direct current can be secured only by rectification.

These characteristics of open-air operation, higher brightness, lower current and the choice of using either alternating or direct current, combined with the uniform brightness and stability of the concentrated arc, seemed ideal.

A wide variety of metals and alloys was tested in the search for a substitute for the platinum used in the first experimental lamps. None proved to be as satisfactory for the purpose as nickel. Nickel is classified in the same periodic family group as platinum and it has somewhat similar characteristics. When subjected to high temperatures in the presence of oxygen, it oxidizes very slowly. The first thin film of oxide which forms on its surface acts as a protective coating which retards further oxidation.

Zirconium oxide was used as the filling material for the first of the new-type electrodes. It worked fairly well but had two major defects. Zirconium oxide is a conductor of electricity only when it is heated to a dull red heat. Thus, it is difficult to strike an arc between such electrodes when they are cold. The arcs are started with a high-voltage pulse generated by a choke and vacuum-switch combination, such as is now used with the standard type of argon-filled concentrated-arc lamp. When zirconium oxide filling was used in the new electrodes, the arc had to be established first to the outer metallic tube. The heat of this arc then raised the zirconium oxide to the temperature where it became conducting and the arc would then strike to the oxide surface. This is the same sequence of events as occurs in the argon-filled type of concentrated-arc lamp during the forming operation. In the enclosed lamp the zirconium-metal film formed during manufacture is established for the life of the lamp. The open-air arc, however, must be reformed each time it is started, for the zirconium-metal film which is produced during operation burns to the oxide the instant the current is shut off. What was needed was some material that could be added to the oxide to make it conductive when cold so that the arc could strike directly to the oxide when the lamp was being started.

The second major difficulty with plain zirconium oxide as a filling material was the poor bond between it and the outer tube. The fused oxide bead which forms on the end of the electrode during operation could be easily knocked off.

A number of materials such as carbon, carborundum and other electrically conductive substances, which could withstand high temperatures, were mixed with the zirconium oxide filling in an attempt to make it conductive when cold. These either burned out of the mixture quickly or poisoned the oxide so that it would not maintain a normal-type concentrated arc. Zirconium-metal powder was tried as a filling material. This construction is shown in Fig. 1. It was pressed into the nickel tube under considerable pressure and then sintered at a bright red heat in an atmosphere of argon or nitrogen. It was hoped that the solid zirconium-metal core thus produced would bond tightly to the nickel tube so that, during operation, only the ex-

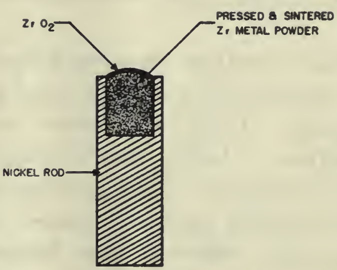

Fig. 1. Section through open-air type of electrode.

posed end of the zirconium would oxidize. If this oxide cap was thin, the starting spark could jump through it to the underlying zirconium metal to give easy starting.

Such electrodes did start easily the first time they were used but, after a few hours of operation, all of the zirconium metal had been progressively converted to the oxide and the electrodes were no better than those which had been packed originally with zirconium oxide.

The next step was an attempt to find some material that could be mixed with the zirconium metal which would protect all but the active end of the zirconium core from oxidation. Powdered nickel, in the proportion of about one part of nickel to three parts of zirconium-metal powder, was found to produce a mixture which would not progressively oxidize throughout its entire volume as had the pure zirconium. These electrodes would acquire only a thin cap of oxide at the active end and the underlying conductive nickel and zirconium

mixture remained to aid in starting the lamps. The zirconium oxide caps were well bonded to both the nickel tube and the underlying metal.

It has been found since, that an even better electrode is produced if a few percent of other materials which act as unrecoverable "catalysts" or accelerators are added to the zirconium nickel mixture. This apparently increases the electrical conductivity through the fused-oxide cap when the electrode is cold and thus aids starting.

The exact composition of the core mixture does not seem to be critical. At the moment, an electrode using 87% zirconium, 8.7% nickel and 4.3% other materials is giving excellent results. This mixture is pressed into the nickel cups under high pressure. The electrodes are heated in an atmosphere of nitrogen to a temperature of about 1000 C when a reaction takes place in the core material, as is indicated by a sudden glowing of the zirconium mixture. After this treatment, the core is very hard and the electrodes are ready for use.

When operating on direct current, one of these electrodes serves as the cathode. Copper has been found to work well as the positive electrode. Two of the sintered zirconium electrodes are used for a-c operation. This, of course, results in two equally brilliant luminous sources which are very close together. If a single source is required, the electrodes can be arranged so that one spot is obscured. For applications where a single luminous spot is not essential, the light from both electrodes of the a-c lamp can be utilized. In this case the luminous output of the a-c lamp is double that of the d-c type. The luminous spots of the a-c and the d-c lamp are quite similar in diameter and brightness. The major interest has seemed to be in the a-c version of the new lamp. For this reason, all of the characteristic performance data quoted in this paper are for a-c lamps.

Figure 2 shows one of the new lamps in operation. This is a 1-kw a-c lamp and the electrodes are arranged at right angles to each other. In the front view, the full end of one electrode can be seen. The luminous spot is very sharply defined. The arc stream itself is relatively nonluminous. This fact is demonstrated further in the side view photograph where the outline of the full-arc stream and flame are only faintly visible while the images of the molten zirconium pools have literally burned themselves into the film. Measurements show that the electrodes are 26 times as bright as the arc flame.

When the lamps are operated on 60-cycle alternating current, the

Fig. 2. Photograph of 1-kw arc in operation: left, front view; right, side view.

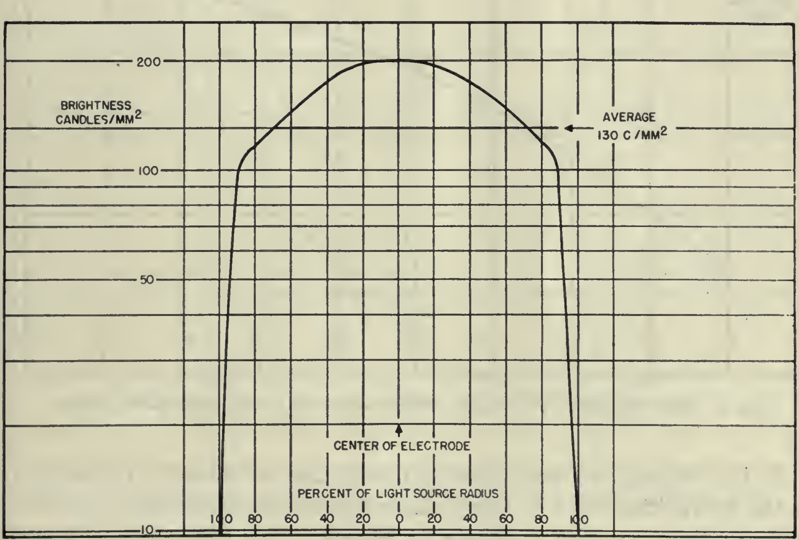

Fig. 3. Brightness distribution across source, 1000-w open-air concentrated-arc lamp.

light has a 16% modulation at 120 cycles. The modulated component originates largely in the arc stream.

The brightness distribution across the luminous spot on the electrode of a 1000-w lamp is shown by the curve of Fig. 3. The increased brightness at the center of the spot is due to the light from the arc

stream which is superimposed upon that originating from the molten zirconium pool. The temperature and brightness of the pool are a characteristic of the zirconium itself and depend upon its melting and boiling temperatures, electron emission characteristics, thermal conductivity and other physical and electrical properties. For this reason, the intrinsic brightness of a lamp is substantially independent of its size.

If hafnium is used in the lamp in the place of zirconium, the brightness of the lamp is doubled. Hafnium is much too expensive, however, for commercial use.

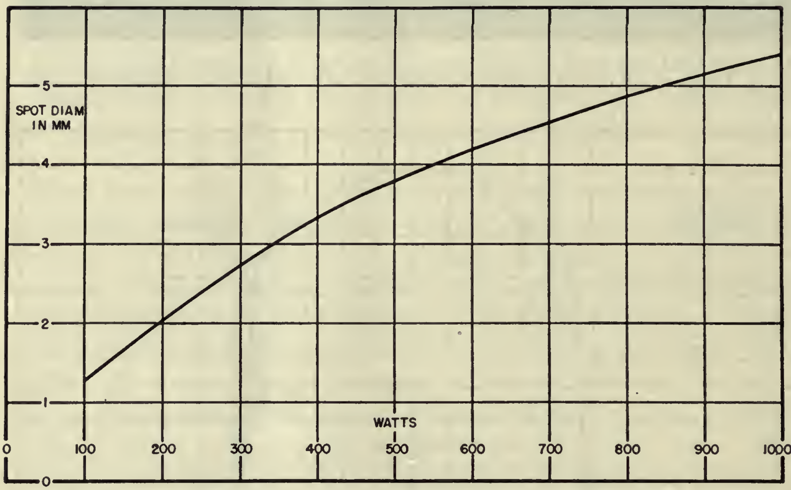

Fig. 4. Spot diameter vs. watts, 1000-w open-air concentrated-arc lamp.

As the wattage is raised, the luminous area increases in proportion to the power expended. The relationship between the spot diameter and the lamp wattage is shown in Fig. 4. The 1000-w lamp has a luminous spot diameter of about 5.4 mm.

An electrode of a given diameter can be operated over a considerable range of current. If the input is too small for the size of the electrode, the luminous spot will cover only a small portion of its end. It may be unstable in its position, for it can establish itself anywhere on the end of the electrode and it may wander during operation. The brightness and efficiency will be somewhat below normal because of the power radiated by the proportionately excessive size of the elec-

trode. At the other extreme, if too much power is put into an electrode, the luminous area will spread to the sides, and the end of the electrode will become rounded and hemispherical. Ordinarily, an electrode works reasonably well over a two-to-one range in current.

As the current is increased the voltage decreases, as is shown by the curve of Fig. 5. This shows that the new lamp has a negative resistance characteristic, like any other arc, and must be operated with proper ballast in its power supply. The voltage drop across a lamp depends upon both the current and the length of the gap between the electrodes.

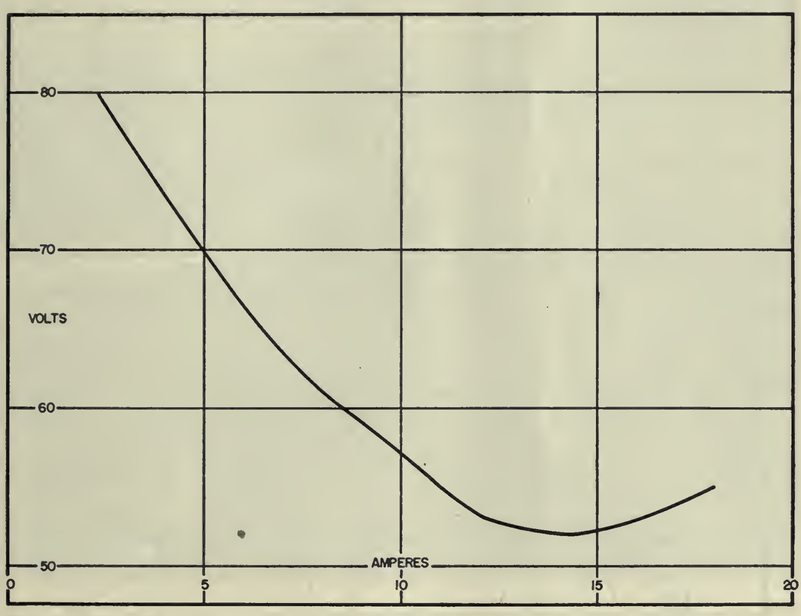

Fig. 5. Volt-ampere characteristic, 1000-w open-air concentrated-arc lamp.

The wattage versus candlepower relationship is shown in Fig. 6. At 1 kw the new lamp produces three candlepower per watt of power input.

The spatial distribution of the light from an electrode depends upon the flatness of the zirconium pool. If the electrode is operated at a low current in proportion to its size, the end of the electrode will be quite flat and the spatial light distribution will follow the cosine law. With higher currents, the electrode end becomes round and the light

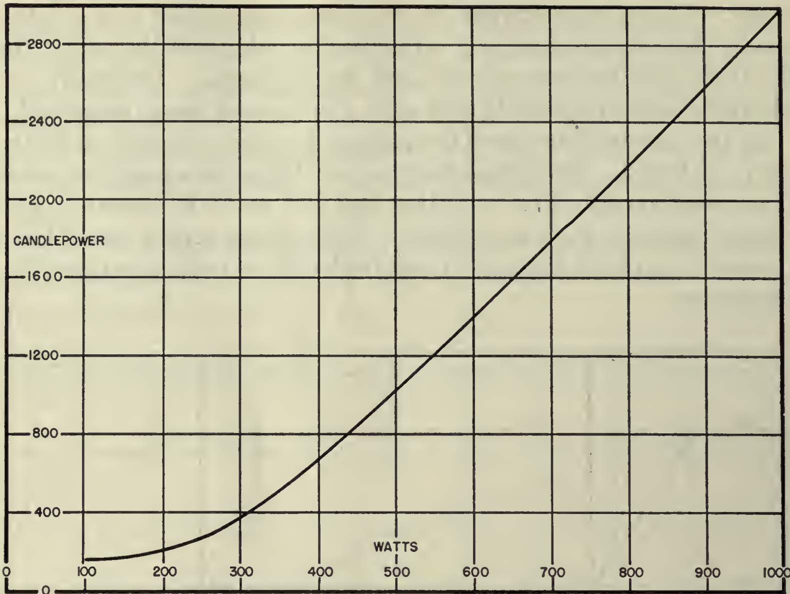

Fig. 6. Candlepower vs. watts, 1000-w open-air concentrated-arc lamp.

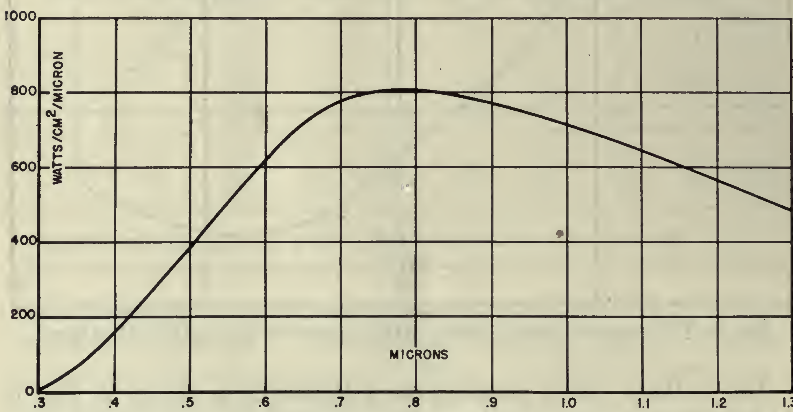

Fig. 7. Spectral energy distribution, 1000-w open-air concentrated-arc lamp.

distribution approaches that of a luminous hemisphere. Measurements show that the pool is normally only slightly rounded.

The total light output of a 1000-w lamp is about 20,000 lm (lumens). The efficiency is thus 20 lm/w. This figure compares favorably with the lumen efficiency of other light sources.

The color temperature of the light produced by the new lamp is about 3600 K (degrees Kelvin). The radiant energy has a spectral distribution in the infrared, visible and near ultraviolet as is shown in Fig. 7. This is substantially the curve of a black- or gray-body radiator peaking around 8000 A (Angstrom units). In addition to the visible light, there is a strong continuum extending far into the infrared and ultraviolet regions of the spectrum. A spectrogram of the ultraviolet radiation is given in Fig. 8. The upper of the three films is of

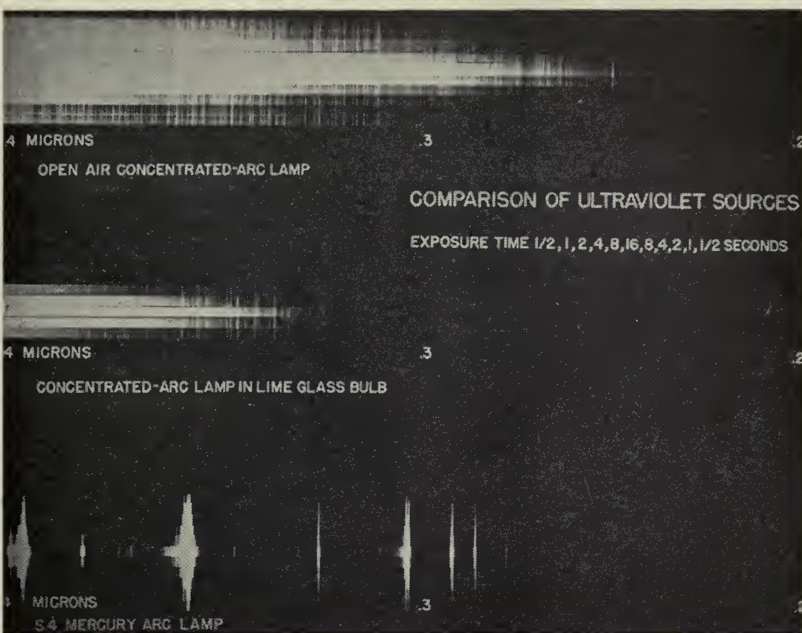

Figure 8.

the open-air concentrated-arc lamp in the spectral interval between 4000 and 2000 A. The eleven individual traces were taken at exposure times of ½, 1, 2, 4, 8, 16, 8, 4, 2, 1, and ½ sec respectively. It can be seen that the open-air arc has a strong continuum superimposed by a line spectrum which extends well toward 2000 A. Similar spectrograms of the conventional concentrated-arc lamp in a lime glass bulb and of an S4 mercury vapor lamp are given for comparison. When the new open-air lamps are operated unenclosed by glass, care must be taken by the operator to avoid sunburn and eye injury.

During the early work with electrodes operating in air from alternating current, it was thought that there would be no appreciable loss of zirconium during operation. This seemed to be confirmed by tests which showed no loss in weight but even a small gain in weight during the first few hours of burning. More extended measurements show that the electrodes first gain and then lose weight. The gain comes from the oxygen taken from the air to produce the zirconium oxide cap. After this cap is once fully formed, the weight decreases at a rate of about 0.05 gram or 0.0017 oz/hr for the ¼-in. diam. electrode burning at 650 w. This represents a reduction in the length of the electrode of about .01 in./hr. The erosion characteristic of a ¼-in. diameter electrode at various wattages is shown in Fig. 9.

This loss is due in part at least to the use of alternating current to operate the lamp. The mechanism of recapture of escaping zirconium atoms by ionization and attraction, which is so effective in the enclosed lamp, is disturbed by a-c operation. The reversing potential and the periods of zero current during the a-c cycle give greater opportunity for the escape of zirconium atoms from the region of the electrodes.

The ¼-in. diameter electrodes have a tip of active material which is about ¼-in. in length. Their life versus wattage characteristic is shown in Fig. 10. They last for about 24 hr when operating at 650 w and for about 6 hr at 1000 w. Electrodes can be made with several inches of active material. They should last for several hundred hours.

The nickel tube and the zirconium core burn down together. The length of an electrode gives a sure indication of the number of hours of use remaining in it. When the active material has been entirely consumed, the lamp goes out and new electrodes must be inserted. A new electrode forms and reaches full brilliancy during the first two minutes of operation.

It is estimated that replacement electrodes can be produced to sell at a price which will make these new lamps competitive with other types of high-intensity sources.

The rate of burning of an electrode depends upon its diameter and the number of watts applied to it. A ¼-in. diameter electrode loses .017 oz/hr at 650 w. This is an exceedingly small amount of material. The products of combustion have been judged by the U.S. Public Health Service to be nontoxic in the quantities involved and to con-

stitute no health hazard. Thus, it is expected that for most applications, the new lamp will not require special ventilation.

In the early work with this new lamp, the two electrodes were mounted end-to-end and were rotated during operation at about one revolution per minute. Such a mounting and the rotation were required to keep the arc stream well centered and to maintain the luminous spots on the ends of the electrodes. While such an end-on arrangement of the electrodes worked well in a device such as a searchlight, which employs a large mirror as the light collecting element, it is not adapted to compact optical systems using lenses.

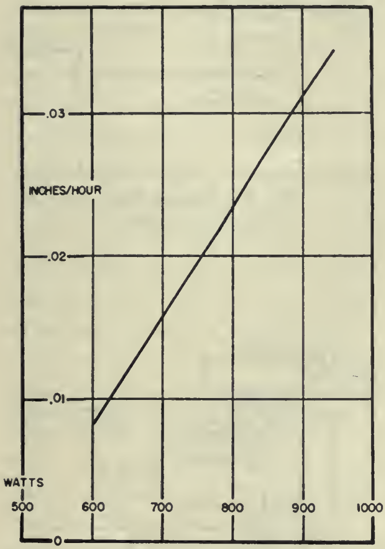

Fig. 9. Electrode erosion vs. watts, ¼-in. diam. electrode.

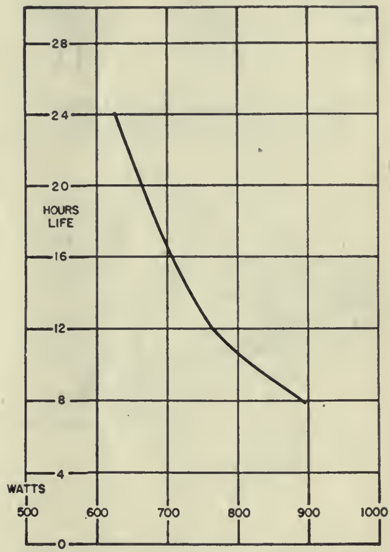

Fig. 10. Electrode life vs. watts, ¼-in. diam. electrode with core ¼ in. long.

A mounting arrangement was tried in which the electrodes were at right angles to each other, as in some carbon arcs. Such a mounting is shown in drawing A of Fig. 11. With this disposition of the electrodes, it should be possible to collect practically all of the light from either electrode with a comparatively small lens. It was found, however, that the arc tended to concentrate on the edges of the two electrodes where they were nearest together, as shown in B of Fig. 11, and produce two luminous discs whose planes were parallel and in-

clined at an angle of 45° with the axes of the electrodes. As a result, little light reached the lens.

The luminous spots could be brought to the center of the end of each electrode if the electrodes were spaced so far apart that the arc stream was carried up in an arch-shaped path by the convection currents in the air as in drawing C of Fig. 11. This arrangement was unstable, however, for with the slightest draft, the arc would either shorten and produce the parallel discs of light or lengthen and blow out.

A suitable solution to the problem was found in a magnetic control system which employs a differentially wound electromagnet which is

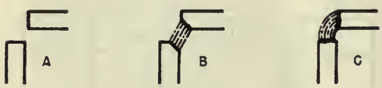

Fig. 11. Types of electrode and arc stream arrangements.

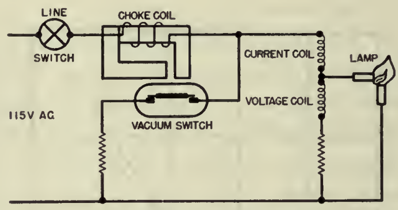

Fig. 13. Choke type of power supply.

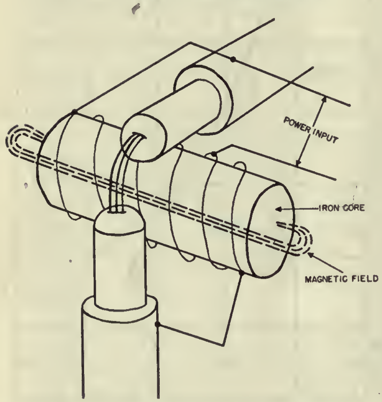

Fig. 12. Differential magnetic arc control system.

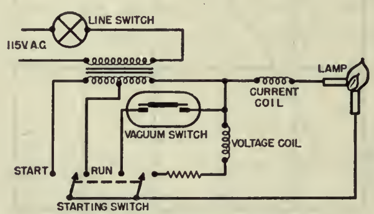

Fig. 14. Transformer type of power supply.

mounted at right angles to the two electrodes and on a line which bisects the angle between them, as shown in Fig. 12. One winding of this coil is connected so that it is in series with the electrodes. Thus, its magnetic effect is proportional to the current being drawn. It is poled so that the arc stream is deflected outward and away from the electromagnet by its reaction with the magnetic field. A second winding on the same iron core is connected across the two electrodes so that its magnetic field is proportional to the voltage across the arc and it is poled to pull the arc in toward the electromagnet.

In operation, the field of one coil tends to neutralize that of the other as long as the arc stream is in the correct position. If the arc tends to shorten, the voltage coil is weakened, the current coil is strengthened and the arc is forced out to a longer path. When the arc stream tends to become too long, the opposite action takes place and the arc is pulled back to its proper position. Thus, the arc stream is under constant automatic control. A small, permanent magnet is placed near the arc so that its field is at right angles to that of the electromagnet. This gives the arc stream lateral stability.

A lamp using this magnetic arc control system not only made it possible to operate the electrodes at right angles to each other and to obtain a good light output but also permitted the luminous spot to be held so accurately on the ends of the electrodes that rotation of the electrodes is not necessary. In addition, the arc stream is so well controlled that spacing between the electrodes becomes very noncritical. As a result, such a controlled arc can be started and, as the electrodes erode very slowly, it will operate for several hours unattended and without adjustment. The maximum length of time possible between adjustments of the electrodes depends somewhat upon the open circuit voltage of the power supply. A designer has the choice of producing a small light power supply unit with a low lamp supply voltage which may require adjustment of the electrodes of the lamps operated by it every half hour or a larger, heavier, higher voltage unit which will allow longer intervals between adjustments.

Figure 13 shows the circuit diagram of a very simple power supply unit. It consists of a choke coil and a vacuum switch combination which produces the high voltage pulse required to start the arc. The starting sequence is as follows: The two electrodes are brought together so that the zirconium oxide caps are touching and the power unit is turned on. Current flows from one side of the line through the inductor, the vacuum switch and current-limiting resistor to the other line wire. This produces a magnetic field around the choke coil which in turn lifts the armature of the vacuum switch and opens it suddenly. The resulting inductive pulse, generated in the coil, is sufficient to start a current flowing through the electrodes. Once started, the arc continues. The current is limited by the inductor. The magnetic field holds the vacuum switch in the open position.

This same type of power unit can be used to start and run the lamps on direct current if a suitable current-limiting resistor is connected in series.

A better power supply for a-c operation is shown in Fig. 14. This employs a high-leakage type transformer to send a constant current through the arc. Starting is made easier by applying about 300 v to the electrodes when the starting switch is in the "Start" position. The vacuum switch operates as before to produce the starting pulse. A 1000-w power supply unit of this type is shown together with a lamp in the photograph of Fig. 15. This power unit measures 6 × 6 × 7 in. and weighs 27 lb.

Fig. 15. Experimental 1-kw a-c open-air concentrated-arc lamp and transformer unit.

Automatic starting and electrode feed are incorporated in the unit diagramed in Fig. 16. The electrodes are mounted so that they can be brought together or drawn apart by the operation of a small two-phase motor, advancing or retracting depending upon its direction of rotation. One winding of the control motor is connected with a phase-shifting condenser in series across the 110-v a-c supply line. The voltage which is applied to the second winding of the motor is obtained from two sources. The first voltage is that across the secondary of the transformer marked A. This is a small step-up transformer whose primary is in series with the arc; thus, its secondary

voltage is proportional to the arc current. The second voltage is that across the arc. Since these two voltages are in phase they can be connected so as to oppose each other.

At the selected arc current and electrode spacing, the voltage from transformer A exactly equals the voltage across the arc and the resultant, which is applied to the motor, is zero. Thus, the motor and the electrodes are stationary.

As the electrodes erode away, the arc voltage tends to increase and the current to decrease. This upsets the voltage balance in the control circuit and causes the motor to operate in a direction to reduce the electrode spacing. If the spacing is too close, the opposite action is produced. The rate of correction is proportional to the amount of correction needed. During starting, before the arc is established, there is voltage across the electrodes but no current flowing, so the control motor operates at a high speed and brings the electrodes

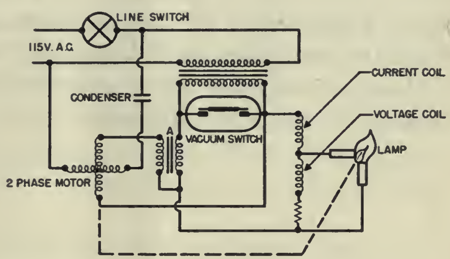

Fig. 16. Power supply with automatic control of electrodes.

together quickly. As soon as the arc is struck, the electrodes are drawn apart and maintained at their proper spacing.

With this automatic start and feed arrangement, the lamp can be operated without any attention except the periodic replacement of the electrodes which may be at intervals of several hundred hours.

The high intensity and the uniform brilliance of the luminous source of the new lamp make it particularly useful in projection applications. An optical bench has been set up, simulating the optical system in a 16-mm projector in which the light source is a 1-kw open-air concentrated arc. The condenser is a special one designed by the Fish-Schurman Co. for this type of work. A standard 16-mm film gate and a DeVry 2-in. $f/1.6$ projection lens complete the system. This combination produced a little over 2000 screen lumens. If a shutter loss of one-third is allowed, a final screen illumination of better than 1300 screen lumens is indicated.

There is no reason why larger wattage lamps cannot be built and applied to larger projection equipment. There is also the possibility of using the 300-w open-air concentrated-arc lamp in an 8-mm projector. The power supply for this size of lamp can be made cheaply from a standard 400-w mercury-vapor lamp transformer and a vacuum switch. The combination of this lamp and power supply is very simple to operate. This unit was designed particularly for laboratories where a compact and stable high intensity source of visible, infrared or ultraviolet radiation is required.

In photographic flood and spot lighting, the new lamp has the advantages of unusual stability, good lumen efficiency, small source size, a continuous spectral distribution and a high and constant color temperature.

In general, the new lamp should work well in the many applications now utilizing the low-intensity carbon arc, but with its increased stability and ease of operation, long electrode life and a-c operation it will undoubtedly be used in many places where the carbon arc would be unsuitable. It is hoped that the new Western Union Open-Air Concentrated-Arc Lamp will prove to be a valuable new tool for the solution of lighting problems.

Light Measurement For Exposure Control

By DON NORWOOD

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Summary—This paper defines the various factors that are involved in photographic exposure control. The relationships of these factors are developed under special and general conditions. The importance of the key-light intensity and relative location of source is shown. A formula for determination of setting of camera exposure controls is developed. Practical application of the fundamentals to the design of photographic exposure meters is discussed.

In October of 1940, I presented to the Society of Motion Picture Engineers a treatise entitled "Negative Exposure Control."[1] That paper covered some phases of exposure control matters. It also introduced an exposure meter which had been invented and developed by the author. That exposure meter was designed to measure incident light. It had a unique type of light collector in the form of a translucent hemisphere.

Since that time tens of thousands of hemisphere-type meters have been manufactured and extensively used in professional and amateur practice. Their superior qualities have been demonstrated under all types of conditions. However, the hemisphere-type meter represents only one facet of the broad project. There are parallel types of devices by means of which the basic theory may be put into practice. The general situation has now evolved to the point where the status of contingent matters, such as patent protection, makes possible the presentation of the basic theory on the subject.

This paper presents the basic theory. In line with present-day conditions, particular attention will be devoted to the matter of exposure of natural color films of the monopack type, such as Kodachrome, Ektachrome and Ansco Color. Full cognizance is given to the fact that these color films are reversal films which permit no compensating

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latitude in printing exposure. It may be noted that original exposure for such films must be much more closely controlled than for black and white films. A degree of exposure accuracy that is suitable for color films will also be quite suitable for black and white films, but the converse is not necessarily true. For these reasons the problem involved in exposure of color films will be considered in some detail.

Theory of Exposure Control

Presentation of the theory of exposure involves analysis of a photometric-photographic complex. This photometric-photographic complex is composed of a number of variables. In fact, there are so many variables that it is not advantageous to immediately include all of them as variables in the first analysis.

It has been found desirable to consider first the basic central elements. Fundamental relationships can then be developed for these basic central elements. Following this, the effects of the other variables can be considered. In this manner the relationships involving all elements can be logically developed and carefully considered.

The Special Case

Pursuant to the above, consideration will first be given to a photographic scene arrangement in which all elements of the subject are uniformly illuminated from a fixed light source adjacent to or directly behind the camera. Subject surfaces will be so oriented as to be normal to the light-to-subject axis in each case. This condition may be kept in mind during the following analysis.

The Factors Involved

It is desirable to define the factors involved. First there is the photographic subject. Photometrically speaking, the photographic subject presents a group of assorted reflectances. These reflectances may have values as low as 2%, for black velvet, and as high as 80%, for a white blotter. All other diffuse reflectances will fall between these two in value. Thus the primary concern is with a group of diffuse reflectance values extending from 2% to 80%.

Second, there is the recording medium, the film. Natural color films of the reversal type may be assumed to have an average acceptance range of about 1–40. Within that range there is one place, and one place only, for each value of subject reflectance. Since color films of the reversal type have no compensating latitude in print-

ing exposure, it follows that each value of subject reflectance must fall into its proper place at the time of first exposure.

From the above it may be noted that the natural color films have acceptance ranges which just cover the values which may be encountered in the reflectances presented by a uniformly front-lighted photographic subject.

Third, there is light, which acts as a carrier medium. Light may be said to originate in a source, such as the sun or a lighting unit. From the source the light travels to the photographic subject. From the subject the light travels on to the camera. It passes through the camera lens, past the shutter, and finally impinges on the film. The light which travels from the subject to the camera carries modifications which represent the reflectances presented by the subject.

The intensity of a ray of light which impinges on a point of that subject can be represented by E. Assume that the particular point of the subject upon which the ray impinges has a reflectance of 5%. The intensity of the reflected ray would then be

$$E \times .05 = .05E.$$

If another ray from the same source impinges upon a point of the subject having a reflectance of 70%, the intensity of that reflected ray would be

$$E \times .70 = .70E.$$

Similarly, all other reflectance values presented by the subject, may be represented.

It may be noted from the above that the light acts as a carrier to convey to the camera the reflectance values presented by the subject. It should also be noted that the same light which leaves the source and approaches the subject is that which finally impinges on the film. It has simply picked up certain modifications at the point of reflection. These modifications should be faithfully conveyed, on the carrier, to the film.

Fourth, there are the camera exposure controls. These consist of a diaphragm in the lens to modify the relative intensity of the carrier light which passes through the lens, and of a shutter to control the length of time during which the light is allowed to impinge on the film. These controls are necessary in order to secure a proper exposure of the film.

Now that the four factors involved in exposure control have been identified, it is possible to consider the relationships between the four.

RELATIONSHIPS OF THE FACTORS

It has been noted that the film-acceptance range of 1–40, and the subject-reflectance range of 1–40 are similar in value. The reflectances presented by the subject can be made to fit quite nicely into the film-acceptance range. Thus the factor *Subject Reflectances* is taken care of by the factor *Film-Acceptance Range, with each element of Subject Reflectance falling into its proper niche on the Film-Acceptance Range.*

There are two remaining factors, namely, the *Incident Light* and the *Camera Exposure Controls.* Consider the carrier, the incident light which impinges on the subject and then carries the subject reflectances to the camera. It may commonly have any one of a wide range of values. It may be as low as ¼ ft-c, or it may be as high as 12,500 ft-c. This is a very extended range, being of the order of 1–50,000. It is quite necessary that the carrier be modified to a proper fraction of its original value before it is allowed to impinge on the film. The particular value to which it must be modified depends upon the sensitivity of the film in the camera. (In accord with motion picture photography, it is convenient to think of this matter in terms of a fixed exposure time; however, the reciprocity law applies here as elsewhere.)

The modification is accomplished by the camera exposure controls. If the camera exposure controls are properly set, the carrier, which may be designated as E, will be so modified that each element of subject reflectance will be properly placed on the film acceptance range.

It is worthy of note that the four factors involved in exposure control are thus separated into two independent groups. *Subject Reflectances* are taken care of by *Film-Acceptance Range. Incident Light* (the carrier) is reduced suitably by the *Camera Exposure Controls.*

However, intelligent modification of the carrier E can be made only after said carrier E has been duly measured. A mathematical analysis of the relationships involved will indicate how the measurement may be best accomplished. The following notations will be used:

E = Incident illumination on subject (foot-candles)
B = Brightness of subject (foot-lamberts)
e = Exposure (meter-candle-seconds)
t = Time of shutter opening (seconds)
f = Relative lens aperture (f-stop numbers)
S = Sensitivity of film (ASA Index rating)
R = Reflectance of subject
I = Image illumination (meter-candles)

It may be stated that

$$B = ER \qquad \text{by definition} \qquad (1)$$

Also,

$$I = B \times \frac{4.4}{4f^2} \qquad \text{from Mees,}^{2} \qquad (2)$$

$$I = 1.1 \frac{B}{f^2} \qquad \text{simplified} \qquad (3)$$

Also,

$$e = It \qquad \text{by definition} \qquad (4)$$

$$e = 1.1 \frac{Bt}{f^2} \qquad \text{by substitution} \qquad (5)$$

$$e = 1.1 \frac{ERt}{f^2} \qquad \text{by substitution} \qquad (6)$$

At this point it is necessary to consider the relationship of subject reflectance to print transmittance (in the case of a natural color transparency), which will give a satisfactory picture; also, in turn, the relationship of the final, positive-image transmittance to the preliminary negative opacity; and again, in turn, the relationship of the negative-image opacity to the exposure.

For the purpose of analysis, consideration will be limited to a straight-line approximation to relationship curves for the factors involved. Then, subject-reflectance values must be represented by print-transmittance values which are proportional thereto. Print-transmittance values are proportional to negative opacities. Negative opacities are proportional to exposure values. It therefore follows that exposure values must be proportional to subject-reflectance values,

$$e = k_1 R \qquad \text{where } k_1 \text{ is a constant} \qquad (7)$$

The above equation contemplates the relationships for a color film having a given sensitivity. The equation may be expanded to include the said relationships for color films of any sensitivity by inclusion of the factor S. To achieve a given transmittance in the positive image, the factor e must also be inversely proportional to S.[3] Thus,

$$e = k_2 \frac{R}{S} \qquad \text{where } k_2 \text{ is a constant} \qquad (8)$$

A substitution in equation 6 may now be made, to give,

$$k_2\frac{R}{S} = \frac{1.1\ ERt}{f^2} \quad \text{by substitution} \quad (9)$$

$$\frac{f^2}{t} = \frac{1.1\ ES}{k_2} \quad \text{by rearrangement} \quad (10)$$

Then let,

$$\frac{1.1}{k_2} = \frac{1}{K} \quad \text{where } K \text{ is a constant} \quad (11)$$

$$\frac{f^2}{t} = \frac{ES}{K} \quad \text{by substitution in (10)} \quad (12)$$

$$\frac{f^2}{t} = E\frac{S}{K} \quad \text{by rearrangement} \quad (13)$$

It may thus be seen that the proper setting for the *Camera Exposure Controls*, for a given film sensitivity, is a function of E, the *Incident Illumination.*

It is well to note at this point the necessity for carefully distinguishing between so-called *exposure*, and the *setting* for the *Camera Exposure Controls.* Exposure of each element of area of film is proportional to the relative brightness of the corresponding element of area of the subject. Many, many different exposure-producing values of brightness may, and usually do, simultaneously pass through one setting of the camera exposure controls. However, the setting for the camera exposure controls is not a function of any or all of these brightnesses, as has been held in some quarters. The setting for the camera exposure controls is a function of the incident illumination.

There apparently has been, in the past, a certain degree of confusion on this point. Reference to the foregoing equations should clarify the matter. Exposure of each element of area of film is proportional to the brightness of the corresponding element of area of the subject, other variables being held constant (see equation 5). The exposure value for each element of area of film must represent the particular value of reflectance of the corresponding element of area of the subject (see equation 8). Setting for the camera exposure controls is a function of the incident illumination (see equation 13).

THE GENERAL CASE

Up to this point the problem has been simplified by the assumption that the subject is uniformly illuminated by a light source located behind the camera. Now it is necessary to depart from the simplifying assumption, and consider the effects that are encountered when

the primary light source is found in other positions, and a three-dimensional subject is used. A unique problem arises at this point. This problem derives from the fact that the photographic effectiveness of the incident light changes in value as the light source changes position with respect to the camera-subject axis.

It will be appreciated that if the light source were located directly behind the camera, all parts of the camera-side of a three-dimensional photographic subject would receive illumination from that source. In such a case the photographic value of the incident light would be 100% of the intensity value. If the light source were moved around through 180° from the first position, to a position directly behind the photographic subject, no part of the camera-side of the subject would be illuminated, and the photographic value of the incident light, from that source, would be 0% of the intensity value. If the light source were located at a side position, whereby the light-subject axis formed a 90° angle to the camera-subject axis, with the subject at the apex of the angle, the illumination from the light source would fall on just one-half of the camera-side of the subject.

It is necessary to digress slightly here, and point out that under common photographic conditions there is usually a secondary light source or sources in addition to the primary source. Outdoors the sun is usually the primary light source, the sky is the secondary light source. The intensity of the illumination from the sun is normally about eight times as great as the intensity of illumination from the sky. This means that about 89% of the illumination is from the primary source, and only about 11% from the secondary source. For this reason the primary source may be considered as the controlling factor in exposure determination, and as such, is known as the key-light.

THE KEY-LIGHT

The key-light constitutes the major factor in exposure determination. The key-light establishes the high-light effects on a subject. In the case of color films the exposure must be adjusted to give proper recording for the high lights. The fill-light is useful and necessary to achieve acceptable pictures but is distinctly secondary in exposure control matters. In the case of indoor work the illumination is usually balanced as between key-light and fill-light to provide a pleasing approximation to the natural illumination found outdoors. Again the key-light is the controlling factor.

It is interesting to note the recommendation made by a prominent manufacturer of color films, with respect to exposure: "Expose for the high lights, and light the shadows."[4] This is just another way of stating that the key-light is the controlling factor in the setting of camera exposure controls for color film.

Now it is possible to return from the digression to consider the case of the intermediate positions for the key-light source. In this case the relatively strong key-light falls on just a portion of the camera-side of the subject. The relatively weak fill-light illuminates the balance of the camera-side of the subject. Under these circumstances the photographic value of the illumination is less than when the key-light source is located in the 0° position.

I have engaged in considerable research directed toward a determination of the relative illumination value when the key-light source is located in various positions relative to the observer-subject axis. A parallel problem is the determination of the relative photographic value when the key-light source is located in various positions relative to the camera-subject axis.

The problem appears to lie in two fields, namely physics and physiology. The factors which belong in the field of physics are those of light intensity and the geometrical arrangement of the light source, the subject and the observer. The reaction of the eye of the observer belongs in the field of physiology.

It appears that positive laws for the reaction of the eye are not definitely known for all conditions. It is known that the eye automatically changes its sensitivity as the effective illumination on the subject changes. The exact degree of change appears to be unknown. It was believed that a good approximation to these values for sensitivity change could be obtained by means of taking numerous pictures of a scene, under controlled conditions, while using varied settings of the camera exposure controls. It was assumed that the most pleasing and natural appearing pictures of the scene (with regard to exposure) would be those in which the camera exposure controls had most nearly simulated the action of the eye in response to different lighting conditions.

This method was used as a statistical method, and the results obtained therefrom were empirical in character.

Numerous groups of pictures were made under conditions which will be described. Each group consisted of 12 pictures of one subject. The 12 pictures in each group were made on one strip of film and de-

veloped together, thus eliminating variables which might be introduced by different emulsions or conditions of development. All exposures were made at $\frac{1}{50}$ second shutter time.

The illumination on the subject, for each group of pictures, consisted of a key-light, and fill-light. Illumination contrast conditions were chosen to fit a typical norm of eight to one. In the case of negative-positive black-and-white pictures, all prints received the same printing exposure. In the case of reversal color films, all pictures in each group received identical processing.

The geometrical arrangement of key-light to subject axis and camera to subject axis was varied, so that effects of the variations might be studied. In each group of 12 pictures, three each were made under conditions of straight-front lighting or 0° key-light angle, 45° key-light angle, 90° key-light angle, and 135° key-light angle.

Various lens apertures were systematically used under each condition of key-light angle. At 0° key-light angle the lens aperture for the exposure of the basic picture was derived from use of the formula shown in equation 13, after duly making measurement of incident light intensity, and taking note of the film sensitivity. The picture resulting from this exposure was placed in position #5 in the accompanying Fig. 1. The lens aperture used for this picture was labeled A_5. Additional pictures were made at the 0° key-light angle, one with $\frac{1}{2}$ *f*-stop smaller aperture and one with $\frac{1}{2}$ *f*-stop greater aperture. The resulting pictures were placed respectively in positions #1 and #9, as shown in Fig. 1. The lens apertures used for these exposures were labeled A_1 and A_9 respectively.

A picture, to fit position #6 in Fig. 1, was then made, under conditions of 45° key-light angle. In this case an increment represented by X *f*-stop was added to the basic aperture used for picture #5. Covering pictures, #2 and #10, using respectively $\frac{1}{2}$ *f*-stop smaller and $\frac{1}{2}$ *f*-stop greater lens apertures than used for #6, were made.

The same procedure was followed for the condition of 90° key-light angle, in which an increment of Y *f*-stop was added to the basic aperture A_5. The same procedure was followed for the 135° key-light angle, in which a Z *f*-stop increment was added to the basic aperture A_5.

The twelve completed pictures which constituted each group were arranged in the form shown in Fig. 1. This arrangement provided four columns of pictures in three rows. Each column represented a different condition of key-light angle. Within each column were three different exposures. It was possible to slide each column up or

down relative to the adjacent columns until the pictures across each row matched in appearance.

The groups of pictures were studied visually in order to determine values for X, Y, and Z which would give matching effects across the rows of pictures. It was not difficult to note which pictures appeared "right," and matched in appearance. These tests were carried out with a number of groups of pictures and a number of observers.

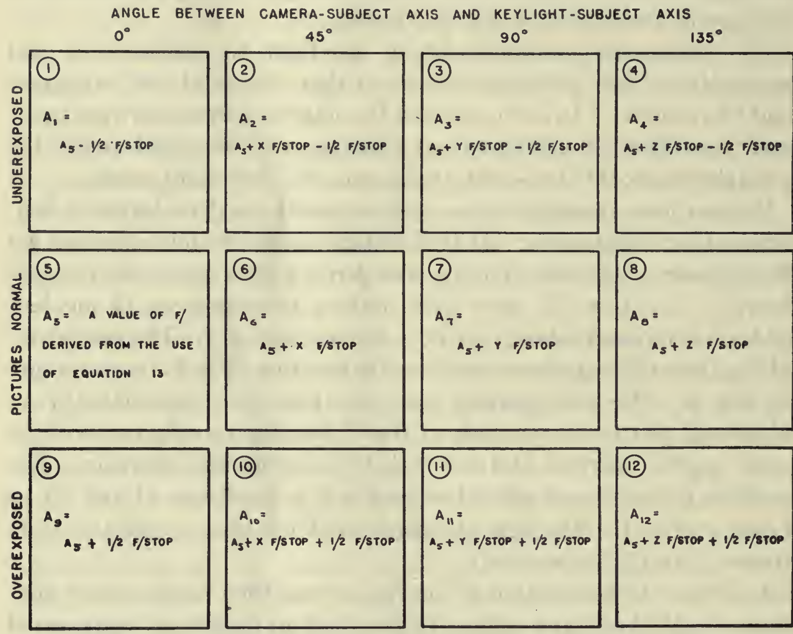

Fig. 1. Study arrangement for test pictures used for determination of relative illumination value of key-light at various key-light angles. Lens apertures designated as A_1 for picture #1, A_2 for picture #2, etc.

The statistical results obtained indicated the following optimum values for X, Y, and Z.

$$X = \tfrac{1}{2}-. \qquad Y = 1. \qquad Z = 2.$$

Translated, these values indicate the following effective values for the illumination when the key-light is located at the indicated positions.

Key-light angle:		Effective illumination value:	
	0°		100%
	45°		75%
	90°		50%
	135°		25%

It is rather interesting to note that these conclusions appear to be supported, at least in part, by empirical data to be found in the exposure instructions regarding front-lighted, cross-lighted, and back-lighted subjects, as issued by some film manufacturers.[5]

The foregoing data indicate that in the general case a simple measurement of key-light intensity is not sufficient to provide a complete answer for exposure control. Neither is a simple measurement of incident front-light sufficient to provide a significant value for exposure control. It is quite necessary to provide for a measurement of the intensity of the key-light, and then to provide means to modify the value so obtained by a factor which is determined by the angular location of the key-light source with respect to the camera-subject axis. Presented herewith is a chart (Fig. 2) showing a key-light source located in various positions with respect to the camera-subject axis. The modifying factor for each angle is also shown.

It is possible to organize the data in Fig. 2 into geometric form. The angle between the camera-subject axis and the subject-key-light axis is represented by θ. The modifying factor is represented by the length of ρ. The resulting curve is clearly shown (Fig. 3), and may be represented by the formula,

$$\rho = 1 - \frac{\theta}{180°} \tag{14}$$

where ρ equals the modifying factor due to the key-light angle. The effective value of the light for any key-light angle then becomes

$$\textit{Effective Illumination} = E \times \rho = E\left(1 - \frac{\theta}{180°}\right). \tag{15}$$

This concept of *Effective Illumination*, which takes into account illumination intensity, and relative positions of observer, subject, and light source, has not heretofore been crystallized or formulated; hence it may well be identified as the *Norwood Effect*. It has considerable significance in photographic work and television work as well as in certain phases of general illumination work.

The value for *Effective Illumination*, derived from equation 15, may be substituted for the simple value E in the previously derived equation 13.

$$\frac{f^2}{t} = \frac{SE\,(1 - \theta/180°)}{K} \tag{16}$$

This gives a formula for the general case, which takes care of the key-

light source in any position. This formula for the general case shows rather plainly that *the setting for the camera exposure controls is a function of the effective value of the illumination.*

An exposure meter is a device whose ultimate purpose is to indicate the proper setting for the Camera Exposure Controls. It then follows

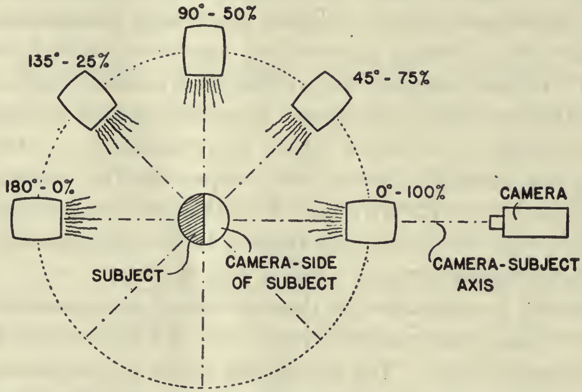

Fig. 2. Photographic arrangement, showing a key-light source located in several test positions. Relative photographic value of light for each angular location of light source is indicated.

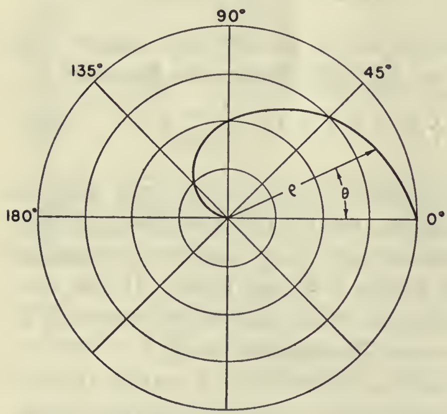

Fig. 3. Polar co-ordinate curve showing relationship between key-light angle and the modifying factor for the relative photographic value of the light.

from the above that an exposure meter should be designed to evaluate the *Effective Illumination.*

An adequate exposure meter must be provided with means for measuring the intensity of the incident light and means for taking into account the angular effect of the key-light source position.

For the constant K, in the above formula, a value of from 26–30 may be used. This figure has been determined empirically. The exact value will depend upon the density of image desired for any given purpose, such as projection through a high-powered projector, projection through a moderate-powered projector or for duplication, etc.

In the derivation of a correct exposure formula, a primary concern has been with those areas of the subject which will carry the high lights. This is in line with the premise that, in the case of color films, exposures should be determined primarily to produce appropriate representation of the high-light areas. Experimental results have confirmed the validity of the premise.

There is a terminal limitation on the key-light angle. In the case of common photography both primary and secondary light sources are usually present. Under these conditions, should the angle between the subject to primary-light-source axis and the subject-camera axis be greater than 135°, the primary light should no longer be considered as the key-light, or control light. It becomes simply a line-light in effect. The secondary light takes control over exposure controls. The center of the secondary light source would then be considered as the key-light source position.

Based upon the fundamental equation 16, various exposure meters have been designed and constructed.

THE HEMISPHERE METER

One exposure meter is that instrument which uses a translucent hemisphere for a light-collector in front of the photovoltaic cell (see Fig. 4). In use, this instrument is placed at the location of the photographic subject, and so oriented that the axis of the hemisphere lies along the subject-camera axis. When so positioned, the instrument acts to measure simultaneously the intensity of the incident key-light, and modify the intensity reading by the angular location factor of the key-light source.

The hemispherical light-collector accomplishes this dual function in the following manner: With a 0° key-light, the illumination will fall on all parts of the hemisphere and a reading of 100% of the intensity value will be obtained. With a 90° key-light, only one-half of the hemisphere will be illuminated by the key-light. It follows that a correct 50% downward modification of the intensity value is obtained. Similarly, with a 45° key-light, a 25% downward modification is achieved. With a 135° key-light, a 75% downward modification is achieved.

The end result is that whatever the intensity of the key-light, and whatever the angular location of the key-light source may be, the hemisphere-type incident light meter correctly evaluates both factors and gives an answer which results in a correct exposure for the conditions prevailing.

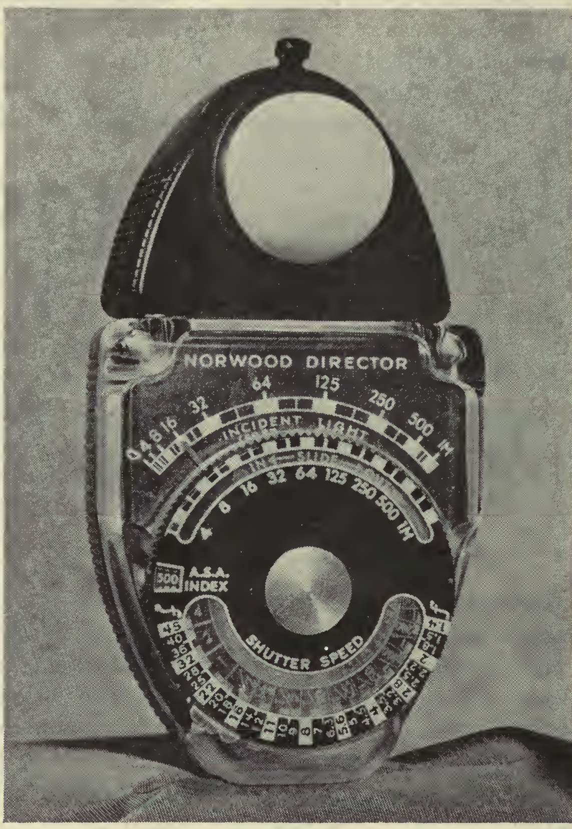

Fig. 4. Exposure meter designed around hemisphere light-collector.

A comprehension of the underlying principles involved, as presented within this paper, will show why the hemisphere-shaped light collector functions perfectly for the purpose. Light collectors of odd shapes, fitted to exposure meters, and designed to be aimed at camera location from subject position, may function in a limited manner. They may operate under conditions of 0° key-light and/or 45° key-light.

Usually however, they fail rather badly under conditions of 90° key-light, and are even more misleading under conditions of 135° key-light. Only the hemisphere form takes care of all these conditions.

THE KEYLITE METER

However, another exposure meter has been designed and built upon the basic foundation presented herein. This is an instrument known as the Keylite meter. This instrument is built with a light collector which is only slightly curved. In operation, it is always pointed at the

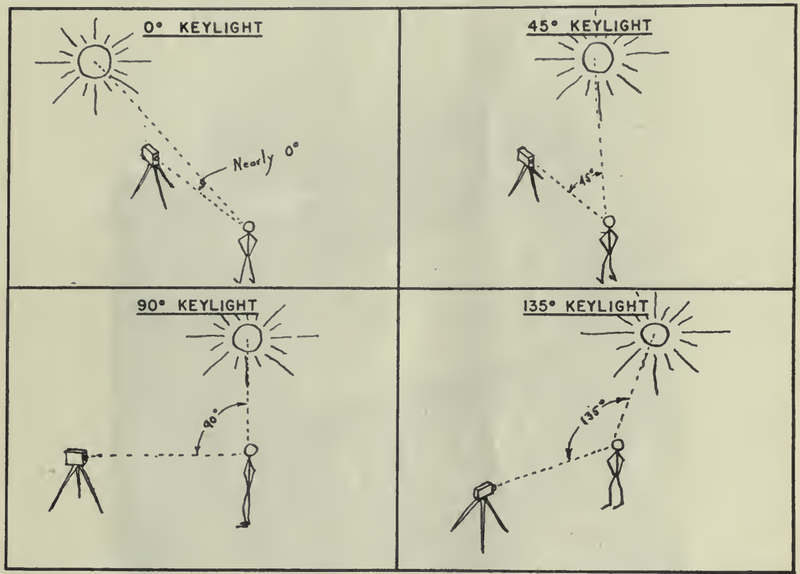

Fig. 5. Chart illustrating the four basic key-light source positions.

key-light source. The primary reading so obtained is that of key-light intensity. The intensity reading so obtained is used directly on a computer device. The computer device has scales which take into account key-light intensity, key-light angle and film sensitivity, and give significant readings for camera lens aperture and shutter time.

The key-light angle is estimated by the operator. In practical work it is only necessary to classify the key-light source as being in one of four broad location groups. The groups include: 0° angle, 45° angle, 90° angle, and 135° angle (see Fig. 5). This classification is rather easily accomplished by the operator.

There are certain very desirable features inherent in the Keylite-type of meter. It is a meter that provides most efficient use of cell and microammeter, since the light collector is pointed directly at the source of illumination. In this manner greatest sensitivity is achieved. It is a satisfying type of meter to operate since it is a maximum-reading type of instrument. That is to say, the operator may point the instrument at different angles until the maximum pointer deflection is noted. The maximum reading is the significant reading. To most operators this feature is rather gratifying because it gives a sense of security in having obtained the absolutely correct reading.

Fig. 6. Exposure meter designed to measure the key-light.

It is probably unnecessary to point out that there are other types of exposure meters which may leave the operator quite uncertain, since relatively small changes in angular position of the meter may produce large changes in readings, and the operator has no sure guide as to which reading has significance.

The Keylite-type of meter has great versatility. It may be used at the position of the subject for indoor pictures. For outdoor pictures it may be used at the position of the subject if desired, or, since out-

door illumination is usually quite uniform over extended areas, it may be used at the position of the camera, or any other place where the illumination is the same as that on the subject.

Due to the fact that the meter is equipped with a light collector which has an acceptance angle of near 2π steradians, the meter may be usefully employed to measure both key-light intensity and then fill-light intensity. A comparison of the two values will serve to indi-

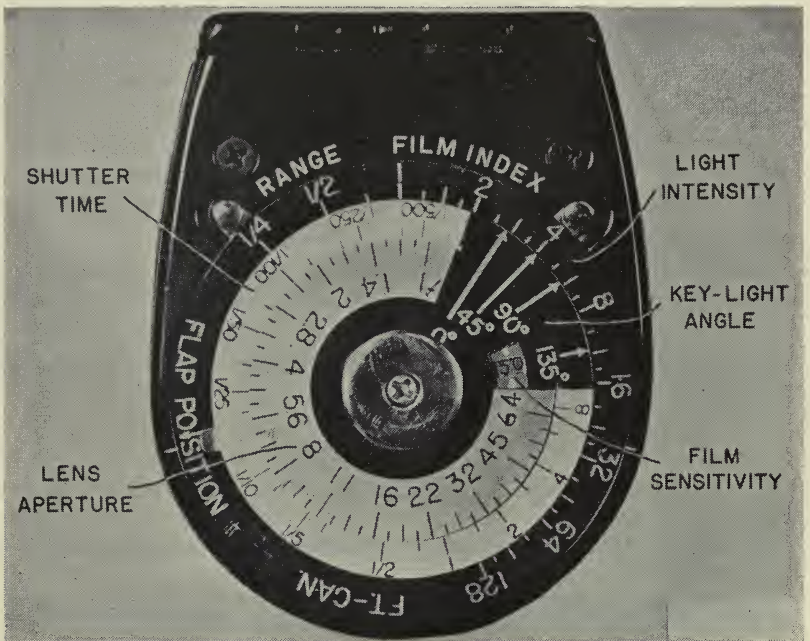

Fig. 7. Special computer designed to solve equation 16.

cate the illumination contrast. This factor is quite useful in the case of color films. It is also significant in the case of black-and-white films, where uniform light balance in a series of scenes is desired.

Figure 6 shows the Keylite meter. The instrument is quite compact. The scale is clear and simple, being calibrated directly in foot-candles. An exponential type of scale is used because of its suitability for photographic work. The scale covers two ranges, namely, 0–128 ft-c and 0–12,800 ft-c. These two ranges provide accurate readings

from ¼ to 12,800 ft-c, which covers all general photography. A hinged range-changer mask is provided to fit over the cell.

The special computer is shown in Fig. 7. The computer is designed to solve formula 16 which takes into account the *Norwood Effect* for illumination,

$$\frac{f^2}{t} = \frac{SE\,(1 - \theta/180°)}{30}$$

This computer is unique in that it incorporates a scale to modify the value of any given key-light intensity according to the angular location of the key-light source.

Many other arrangements of the various scales of the computer are possible. It is also possible to substitute the words "front-light" for 0° (light), "three-quarter light" for 45° (light), "cross-light" for 90° (light), and "back-light" for 135° (light). Such variations might be desirable for some purposes. They all follow the same principle of the solving of the equation shown above.

The solution of this equation gives the most perfect exposures for color film yet achieved. As previously mentioned, the exposure accuracy which is satisfactory for color films is also quite satisfactory for black-and-white films. The exposure meters which are designed around the formula are thus very useful devices.

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A Survey of High-Speed Motion Picture Photography

A High-Speed Photography Subcommittee Report

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Summary—**A survey of high-speed motion picture practices was conducted by the Society in 1949. The data collected are presented here, with a review of comments submitted by users of high-speed techniques and equipment. Conclusions are drawn by the author regarding the current availability of such information and also the scope of the survey is commented upon. Recommendations are made concerning the future of photographic instrumentation and the role of the Society in this expanding field.**

In March, 1949, the Society's High-Speed Photography Subcommittee on Requirements prepared and submitted to 150 selected recipients, a questionnaire on equipment and techniques now employed in this field. In preparing the questionnaire, primary consideration was given to the commercially available cameras in the United States because of their general use in a variety of applications. Users were asked to comment on the value of results obtained, and on the future development of suggested cameras, camera accessories and related equipment.

Recipients were selected by the Committee on a basis of knowledge and experience, from a list of known users of equipment. The amount of data requested from each was limited purposely by "brief answer" questions; however, many volunteered additional information, all of which has been included in this report.

Two months after the survey was begun, a summary report was prepared for the committee to study. Although incomplete, that summary presented an encouraging picture. The Committee felt generally that further work would be rewarding and the author was requested to prepare this complete report analyzing at length the information taken from 100 questionnaires. This represents a 67% return and includes data from six replies only partially completed because of lack of equipment or knowledge on the part of the organizations or present representatives.

Presented: October 12, 1949, as a tentative report at the SMPE Convention in Hollywood.

ORGANIZATIONS REPORTING

Table 1 classifies by type the organizations reporting; and Table 2 presents users who are in the industrial category, the largest single group.

Table 1. General Types of Users

Type	No.	%
Universities, research foundations, hospital research groups.....	19	20.2
Industrial..	60	63.8
Governmental agencies (12 of these are military and naval)....	15	16.0

Table 2. Industrial Group Breakdown

Business	No.	Business	No.
Aircraft	11	Food products	1
Electrical equipment	9	Food handling machinery	1
Light and heavy machinery	7	Industrial burner	1
Industrial research laboratories	6	Petroleum	1
Automotive and automotive accessory	4	Camera manufacture	1
Business machine	3	Railroad	1
Arms and ammunition	2	Steel fabrication and manufacture	1
Textile machinery	2	Drinking cup manufacture	1
Valve	1	Vacuum cleaner	1
Soap	1	Chemical	1
Paint spray equipment	1	Ball bearings	1
Can manufacture	1	Cork products	1

In the author's opinion, returns were large enough and sufficiently representative to serve as the basis for numerous useful conclusions.

Although the questionnaire did not inquire about the frequency of camera use or the quantity of film consumed per camera per month, considerably greater footage is generally used by governmental agencies than by commercial researchers. Specific amounts or ratios are not available nor are these figures felt to be particularly significant in the present study.

The contributed data are presented here with the author's accompanying discussion and are arranged by subject rather than in the order of the questionnaire.

CAMERAS

Of the 273 cameras listed in Table 3, there are 240 which may be classed as high-speed. The General Radio cameras are dual purpose;

they may be used for either image- or non-image-forming photography. There were 30 cameras designed primarily for the recording of oscilloscope traces, while two others are not considered as high speed, for their maximum frame frequencies do not exceed 180 frames/sec. In all the succeeding information, however, all cameras and their accessory equipments will be included.

Table 3. Types of Cameras

Designation	No.	Designation	No.
ERPI	5	DuMont-Fairchild Oscillo-Record Camera	15
Eastman High-Speed Camera, Type II	2	Naval Ordnance Laboratory Oscilloscope 6-Trace Camera	12
Eastman High-Speed Camera, Type III	74	White Engineering	3
Kodak High-Speed Camera	3	Bowen-Knapp Ribbon Frame Camera	1
Western Electric Fastax 8-mm	37	Bell & Howell 70-G (125 frame/sec)	1
Western Electric Fastax 16-mm	68	Unknown	1
Western Electric Fastax 35-mm	19	*Total*	273
General Radio Company	28		
NACA 40,000 frame/sec Camera	3		
NACA 400,000 frame/sec Camera	1		

Table 4. Distribution of Cameras Among Users

No. cameras per user	No. users	Total cameras	No. cameras per user	No. users	Total cameras
1	71	71	8	1	8
2	9	18	9	1	9
3	3	9	12	1	12
4	4	16	14	1	14
5	3	15	46	1	46
6	1	6	49	1	49
			Totals	97	273

From Table 4, it is important to note that, although many users had only 1 to 5 cameras, 7 users (government agencies, chiefly military) had among them 146 cameras or 53% of the total.

SUBJECTS PHOTOGRAPHED

The variety of subjects photographed is shown in Table 5. Because of the limiting nature of questionnaires, it was not possible to ascertain what percentage of use is quantitative photography for establishing numerical data as opposed to that used qualitatively, or for visual examination only. For the time being, therefore, a number of ques-

tions will have to go unanswered. It may be seen that those reporting make the largest use of high-speed photography in:

(1) mechanical equipment study and analysis,
(2) electrical phenomena and equipment study,
(3) ordnance studies (including ballistics), and
(4) combustion phenomena research.

Table 5. Subjects Photographed

Subject	No.	Subject	No.
Aerial camera shutters	1	Mechanical equipment	47
Aircraft and aircraft components	8	Medical, aero medical research	1
Automotive mechanisms	1	Medical, vocal cords of humans before and after surgery	1
Ballistic phenomena (including underwater)	7	Milking operations	1
Capillary action (in a centrifuge)	1	Nozzle action	1
Cathode ray oscillograph recording	8	Ordnance, including guided missiles and rockets	14
Chemical reactions	2	Paint spray guns	1
Chronograph recording	1	Parachute testing	1
Cloud phenomena	1	Production machinery, metals	7
Combustion phenomena	11	Schlieren photography, high-speed	2
Compressors	1	Soap film formation	1
Electrical phenomena and equipment	16	Strength of materials, including drop tests, dynamic tensile tests, fracture of materials, stress analysis	7
Explosion phenomena	7	Surface tension phenomena	1
Fluid mechanics, gas	3	Textile machinery	3
Fluid mechanics, liquid	5	Valves and valve springs	1
Food handling and processing equipment	1	Vibration studies	2
Hydraulic equipment	1	Washing action	1
Industrial research	3	Wind tunnel tests	3
Instrument and meter recording	3		
Internal combustion engines	1		

LENSES AND FIELD SIZES

Table 6 shows the lenses currently in use. Six users did not report on lenses and 3 users merely noted that they have a number of lenses of from 25-mm to 15-in. focal length. It must be remembered that most of these lenses are used with the Eastman Kodak, Fastax and General Radio cameras.

Lenses furnished as standard equipment with the Eastman and Fastax cameras make up the bulk of those reported. The longer and shorter focal length lenses are specially mounted to fit these cameras by the user, depending upon his particular needs. Several users report the use of supplementary lenses for close-up work. A number of comments were included in the returned questionnaires:

Table 6. Types of Lenses Used

Manufacturer	Focal length mm	Focal length in.	Aperture (f/no.)	No.
Wollensak	35		$f/2$	18
	50		$f/2$	10
		2	$f/1.55$	2
		2	$f/2$	51
	101		$f/2$	2
	105		$f/3.5$	8
		6	$f/4.5$	3
	25		$f/2.7$	1
		1	$f/1.5$	1
	35		$f/3.5$	1
	50		$f/1.5$	1
	75		$f/3.5$	1
		3	$f/3.5$	1
		4	$f/3.5$	1
	150		$f/3.5$	1
		6	$f/5.6$	1
	250		$f/4.5$	1
		10	$f/4.5$	1
Eastman Kodak	25		$f/1.9$	2
		1½	$f/2$	4
		2	$f/2.7$	2
		2½	$f/2.7$	3
	63		$f/2.7$	29
		4	$f/2.7$	2
	102		$f/2.7$	8
	50		$f/1.6$	1
		6	$f/4.5$	1
Bausch & Lomb	16		$f/4.5$	1
	25		$f/2.8$	1
	32		$f/4.5$	1
		1½	$f/2.7$	1
	48		$f/4.5$	1
	50		$f/3.5$	1
		2	$f/1.5$	1
		2	$f/4.5$	1
	72		$f/4.5$	1
	75		$f/2.3$	1
	112		$f/4.5$	1
	152		$f/2.7$	1
Zeiss	50		$f/1.5$	1
Hugo Meyer		2	$f/1.5$	1
Taylor, Hobson & Cooke	47		$f/2$	1
		3	$f/1.5$	1
		6	$f/4.5$	1
Goertz		4	$f/1.8$	1
		10	$f/4.5$	1
Total				176

(1) Additional lenses should be available for the Eastman Kodak High-Speed Cameras, Type III.

(2) Present focusing devices were reported inadequate and inaccurate, indicating a need for further study and solution.

(3) Lenses of shorter focal length should be available for both Eastman and Fastax high-speed cameras.

(4) Faster lenses were requested. Reference was made to the $f/0.6$ lens recently described by Kaprelian of the U. S. Army Signal Corps.

Table 7. Number of Different Lenses per User

No. lenses	No. users	% of users	No. lenses	No. users	% of users
1	49	51	5	4	4
2	24	25	More than 5	7	7
3	11	11			
4	2	2			

Table 8. Lens Distribution by Focal Length

Focal length mm	Focal length in.	No.	%	Focal length mm	Focal length in.	No.	%
16		1	0.6	75	3	4	2.2
25	1	5	2.8	101	4	14	7.9
32		1	0.6	105		8	4.5
35	1½	24	13.6	112		1	0.6
48		2	1.1	152	6	8	4.5
50	2	72	40.7	254	10	3	1.7
63	2½	32	18.0	381	15	1	0.6
72		1	0.6				

Table 7 shows the number of different lenses available to each user. Tables 8, 9 and 10 cover focal lengths, and field widths and ranges. It may be seen that 35-, 50- and 63-mm (*i.e.*, the standard lenses) comprise 72.3% of those employed.

Field sizes ranging from 1 mm to 500 ft in width were reported. A mean field width smaller than 24 in. obtains in 86% of the photography; smaller than 13 in. in 68%; and smaller than 7 in. in 37%.

While field widths are dictated by the subject matter, it is indicated that lenses, in some instances, have limited the field widths and ranges possible. For instance, users of very small field sizes reported the regular use of supplementary lenses and therefore implied a requirement for somewhat shorter focal length lenses.

To aid in evaluating the range of field widths, the ratio (R) has been employed as follows:

$$R = \text{Field Width Maximum} / \text{Field Width Minimum}.$$

R is shown in Table 10 which covers two-thirds of those reporting, the remaining one-third having reported only in terms of average field size. Field width ranges were generally moderate but these extremes were reported: (1) 1 ft to 400 ft (R = 400); (2) ½ in. to 50 ft (R = 1200) and (3) 1 mm to 30 ft (R = 9000). An R of only 15 or less obtains for 73% of the practice because no greater range was desired or because the range was so limited by available lenses.

Table 9. Mean Field Widths

Mean field width, in.	Frequency	Mean field width, in.	Mean field width, ft	Frequency	Mean field width, ft	Frequency
¾	1	11		1	7½	1
1	2	12		10	8	2
2	4	13		1	9	1
3	3	14		2	12	1
3½	4	15		2	15	1
4	3	17		1	20	2
5	2	18		5	25	1
6	10	24		5	30	1
7	4	28		2	40	1
8	2	36		3	50	2
9	3				75	1
10	2		3½	1	200	1
			6	1	260	1

Table 10. Field Width Ranges

R	Frequency	R	Frequency	R	Frequency	R	Frequency
1.3	1	4.0	1	14	1	42	1
1.5	1	5.0	5	15	1	50	1
1.75	1	6.0	7	24	1	300	1
2.0	5	8.0	1	33.3	1	384	1
2.5	2	8.8	1	36	1	400	1
3.0	3	12.0	3	40	2	1200	1
						9000	1

From Table 11 it may be noted that 75.3% of the apertures were $f/4.5$ or larger; thus, the depth of focus is at a minimum. It is also significant that many report the use of lens apertures in the wide-

Table 11. Lens Apertures Most Frequently Used

f/No.	No.	%	f/No.	No.	%
1.5	5	2.4	5.6	27	12.9
2.0	37	17.6	8.0	13	6.2
2.7	44	21.0	11	8	3.8
3.5	33	15.7	16	3	1.4
4.5	39	18.6	22	1	0.4

open position. Those using smaller than $f/8$ were, in large measure, photographing subjects under daylight illumination at relatively low frame frequencies. The lens aperture used is dependent upon the illumination available, the frame frequency, the exposure duration per frame, the film characteristics, the depth of focus requirements, and other factors, any of which may be seriously limiting. These data indicate indirectly that one of the major problems in high-speed photography is that of providing sufficient illumination intensities.

ILLUMINATION AND ILLUMINANTS

Since the questionnaire did not cite self-luminous subjects, it may be inferred that their use is somewhat greater than the 5% shown in Table 12. Several reported supplementing daylight with artificial lights, and one reported supplementary artificial illumination of a self-luminous subject.

Table 12. Illumination Used

Type	%
Artificial light	80
Daylight	15
Self-luminous subjects	5

Table 13. Types of Illuminants

Type	No.	%
Incandescent	139	86.0
Self-luminous	8	4.9
Chemical (flash bulbs)	6	3.7
Carbon arc	5	3.0
Gaseous discharge lamps	4	2.4

Illuminants are analyzed in several ways in Tables 13–16. Of those users who had only one lighting method available (Table 15), 70% (or 40% of the total users, 38 in number) reported the use of RPS 2, RFL 2, or 750R lamps.

Several reported using no reflectors or improvising with white cardboard or blotting paper.

Because each subject photographed presents an individual lighting problem, it would not be feasible to try to report on: number of light

Table 14. Illuminants Used

Designation	Mfr.	No.	Designation	Mfr.	No.
RSP 2	G.E., Westing.	36	150/PAR/3SP	G.E., Westing.	2
RFL 2	G.E., Westing.	26	Zirconium Arc	Western Union	2
#4 Photofloods		18	500-w Photospots	G.E., Westing.	2
2000-w spots, T48, G 48CP		16	#3 bulbs	Wabash	2
150/PAR/SP (overvolted)		10	RSP 2 (overvolted)	G.E., Westing.	2
750-w spots, T24/14	G.E.	9	1500-w		1
750 R (High-speed Photo)		6	750-w T 20		1
5 kw, G 64		5	150/PAR/FL		1
Stroboscopic	G.E., G.R., etc.	4	10-kw G 96		1
Carbon arcs	Various	4	Auxiliary Field Lighting gear	Military eqpt.	1
1000-w T 20	G.E.	3	Lester Speed Lites	H. M. Lester	1
#2 Photofloods	G.E., Westing.	3	100-w, 6-v	Unknown	1
#31 Flash bulbs	G.E., Sylvania	3	Aircraft searchlight	Military eqpt.	1

Table 15. Number of Lighting Methods per User

	Frequency	%
Only one lighting method available	54	57.0
More than one lighting method available	33	34.5
Self-luminous subjects only	8	8.5

Table 16. Reflectors Used

Type	No.	Type	No.
Built-into lamps	48	10-in. spherical, Bausch & Lomb	2
Mole-Richardson Solarspots	10	Johnson Ventlites	2
Bardwell & McAllister Kegs and 2000-w	8	6-in. Parabolic, 50-in. F.L.	2
Victor 18 in.	6	Searchlight	1
Rosslites 201 and 241	5	Auxiliary field lighting gear, U.S.A.F.	1
Eastman Kodak	4	Lester Speed Lite	1
Special	4	Bantam	1
Elliptical, aluminum, 3-ft F.L.	2	Kliegl	1
Theater carbon arc projector reflector	2	Oleson	1

sources; brightnesses; spectral distribution; the use of reflectors, diffusers and back-lighting; and other practices.

This survey has borne out experience that lighting continues to be one of the most critical fields requiring attention. We should note that 57% of those reporting had available only a single illuminant,

usually a reflector spot or flood. This undoubtedly accounts for much of today's high-speed photography which is of poor pictorial quality.

LIGHT MEASUREMENT

Of the 46% reporting the use of a light meter (Table 17) at least for an estimation of the illumination, many indicated that they also relied upon previous exposure data and otherwise resorted to experience. A number have modified their exposure meters for use under high-speed photographic conditions. For the types of light meters used, see Table 18.

Table 17. Light Measurement Methods

Method	No.	%
Experience	49	51
Meters	45	46
No answer	3	3

Table 19. Interest in Proposed Light Meter for High-Speed Photography

Reaction	No.	%
Interested	72	75.0
Not interested	18	18.7
Undecided	4	4.2
No answer	2	2.1

Table 18. Light Meters Used

Type	No.
Weston	21
General Electric	11
Norwood	4
Own design	2
S.E.I.	1
General Radio 1501A	1
Type not given	14

Table 20. Types of Film Used

Designation	Mfr.	Frequency	%
Super XX Negative	Eastman	84	68.0
Super XX Reversal	Eastman	12	9.7
Kodachrome, Type A	Eastman	9	7.2
Super X	Eastman	7	5.5
Linagraph Pan	Eastman	6	4.8
Triple S Pan Reversal	Ansco	3	2.4
Panatomic	Eastman	1	0.8
Gold Seal	DuPont	1	0.8
301 A Panchromatic	DuPont	1	0.8

The 51% who reported that they resorted to experience exclusively for determination of proper exposure and illumination conditions employed test strips, manufacturers' recommendations, calculations, previous exposure data and, as one put it, an "educated guess."

There was significant response to a question about the need for a high-speed photography light meter of the barrier-layer cell (Table 19). Several felt that a new meter should be reasonably priced, should measure incident-light, should be balanced for the color temperature

of *photofloods* and compensated for reciprocity-law failure and other factors which become critical in high-speed photography.

A few felt that their experience, their satisfaction with self-modified light meters, or an insufficient use of high-speed photography would preclude their interest in the proposed meter. Users of the S.E.I. and General Radio 1501A meters felt that they were entirely satisfactory. One user indicated that a light meter for his particular application, flame-propagation phenomena, could not be made.

It is understood that Weston Electrical Instrument Corp. has developed the proposed light meter and designated it Weston Model 757.[1]

FILM

Since the fastest film normally available for high-speed photography is used in a majority of applications (Table 20), we are justified in assuming that adequate lighting has been found difficult to achieve.

Several recommended the development of black-and-white and color emulsions with increased exposure index characteristics and of new emulsions with extended spectral range and sensitivity to radiation ranging from gamma rays to the far infra-red. In discussions, it was learned that the major film manufacturers are busily engaged in pursuing these goals. A startling increase in emulsion speed is not in the offing; but a slow, steady increase is anticipated.

A number reported requirements for a finer-grained film of higher speed. The characteristics of *fine-grain* and *high-speed* are, for a silver halide emulsion, contradictory since, in general, the faster the film, the coarser the grain. Some users reported preference for the slower, finer-grained films currently available. The reported need for finer-grained films is felt to indicate:

(1) that processing techniques employed have resulted in granularity and grain size increase greater than the optimum for the given emulsion, and

(2) that the users may be erroneously interpreting the relatively poor resolution of their high-speed records as being limited by emulsion characteristics of the film.

In discussing this second point it is desirable to point out that the fastest film generally employed for high-speed photography, Super XX Panchromatic Negative Safety Film, is reported by the manufacturer to have a resolving power of 90 lines/mm when developed in

[1] E. T. Higgons, "Exposure meter for high-speed photography," *Jour. SMPE*, vol. 53, pp. 545–548; November, 1949.

Kodak SD-21. The optical systems of both the Eastman Kodak and the Fastax cameras have much lower resolving power. Alan A. Cook of Wollensak gives the resolution for a Fastax 16-mm camera at *f*/2 (the writer assumes that Cook refers to the use of a 51-mm, *f*/2 lens) as 28 lines/mm in the corners of the image, with an increase to 40 lines/mm at the center of the picture area. He states that at *f*/3.5, 40 lines/mm are resolved over the whole picture area and that these results applied to both Super XX and to Kodachrome.[2] He does not describe the conditions under which these results were obtained.

A number reported that time delays and other difficulties in getting film processed and printed commercially had forced them to develop negative stock, in many cases in makeshift apparatus. They often view the record in that form. A requirement is reported for rapid, portable, foolproof and reliable developing equipment and procedures for both negative and reversal stock, with provision incorporated for overdevelopment where necessary.

One user suggested improvement in film storage qualities but gave no further details.

Frame Frequencies

Use of frame frequencies from 100 to 500,000 per sec (NACA 400,000 frame/sec Camera) as reported is presented in Table 21. Mean values have been used for frame frequencies in cases where they were reported as ranges rather than specific rates.

In general, the most used frame frequencies appear to lie intermediate in the Eastman and Fastax camera ranges, although many users reported using the entire frame frequency range.

Those reporting a need for increased frame frequencies are shown in Table 22, and in Table 23 are shown the frame frequencies desired.

The author is responsible for the range classifications which have not been considered generally for adoption and are at variance with another system of classification as adopted by the committee at large and reported upon by Sandell.[3]

In the study of very high-speed transient phenomena, there is an urgent need for frame frequencies higher than those presently possible with the commercially available cameras.

Those who reported a need for frame frequencies to 10,000/sec

[2] Alan A. Cook, "Lenses for high-speed motion picture cameras," *Jour. SMPE*, vol. 52, pp. 110–115 of Part II; March, 1949.

[3] Maynard L. Sandell, "What is high-speed photography?" *Jour. SMPE*, vol. 52, pp. 5–7 of Part II; March, 1949.

were, in general, users of the Eastman and the 35-mm Fastax cameras. A number of other users felt that higher frame frequencies would not be particularly useful without an accompanying marked increase in resolution.

Table 21. Frame Frequencies Generally Used

Frames/sec	No.	Frames/sec	No.	Frames/sec	No.
750	4	3,500	2	7,500	1
1,000	7	4,000	9	8,000	2
1,500	5	4,500	5	10,000	1
2,000	15	5,000	7	40,000	1
2,500	16	6,000	6	500,000	1
3,000	15	7,000	1		

Table 22. Need for Increased Frame Frequency

Reaction	No.	%
Need increase	41	41.8
Not needed at present	5	5.1
No increase needed	50	51.0
No answer	2	2.1

Table 23. Frame Frequency Ranges Desired

Frame Frequency Range	No.	%
High-speed (275 to 20,000 fr/sec)		
to 10,000 fr/sec	7	16.2
10,000 to 20,000 fr/sec	9	20.9
Very high-speed (20,000 to 500,000 fr/sec)		
20,000 to 50,000 fr/sec	6	13.9
50,000 to 100,000 fr/sec	7	16.2
100,000 to 500,000 fr/sec	1	2.3
Ultra high-speed (greater than 500,000 fr/sec)		
10^6 and faster	1	2.3
Did not know as yet	12	28.2

Interestingly enough, a relatively large number of users reported need for cameras with good operating and photographic characteristics in the lower frequency range of 100 to 500 frames/sec, below normal for the Eastman and the Fastax cameras. It is understood, however, that the 8-mm Fastax camera is rated to operate at a minimum frequency of 300 frames/sec, the 16-mm Fastax at a minimum frequency of 150 frames/sec; and that the Eastman Kodak High-Speed camera may be specially furnished to cover this desired range.

Film Capacity

Table 24 shows that present film capacity is adequate for most needs. It was interesting to find that many felt that the present 100-ft film capacity was much too great. By inference, those whose use is quantitative find that they can obtain useful information with relatively few feet of film.

Table 24. Adequacy of Present Film Capacity

Reaction	%
Adequate	78
Inadequate	22

Table 25. Distribution of Increased Film Capacity Requirements

Film capacity, ft	No.	%
200	8	34.8
300	1	4.4
400	4	17.3
500	4	17.3
1,000	3	13.0
2,000	1	4.4
5,000	1	4.4
Over 5,000	1	4.4

Table 26. Interest in Proposed 35-Mm Time-Lapse Camera

Reaction	No.	%
*Interested	*37	*37.5
Not interested	45	45.5
No answer	17	17.0

* Includes 5 (4.9% of the total) who desired a 16-mm single-frame.

Table 27. Interest in 35-Mm Full-Frame, High-Speed Camera

Reaction	No.	%
Interested	30	30
Not interested	56	56
Not at present	6	6
No answer	6	6
Already have	2	2

These users suggested that means be developed for rapid acceleration to operating speed. A number thought that the use of leader attached to a few feet of unexposed film would be a possible solution to this problem. One user reported the installation of a brake on the feed roll of the Fastax camera which permitted him to take four to five runs at low speeds on a single 100-ft roll of film. The acceleration problem remains, however.

Film capacity requirements, of course, depend upon the nature and duration of the phenomenon being studied and the precision of event synchronization. In some cases, the survey brought out that with better event synchronization, present film capacity would prove adequate.

The 22% who reported inadequate film capacity desired the larger capacities shown in Table 25. Transient phenomena of extended duration sometimes require total exposures longer than can be re-

corded with a single Eastman or Fastax Camera. In some cases, the long acceleration period of these cameras has resulted in a requirement of at least 100 ft of film exposed at a given frame frequency.

Some users have employed several cameras operating in closely timed sequence to cover the total period of time desired.

One "unique" suggestion called for the development of a 500- to 10,000-frame/sec camera with a 6-minute capacity at 10,000 frames/-sec! A 235,000-ft roll of 35-mm film would do the trick! Only 44½ miles long!

PROPOSED TIME LAPSE CAMERA

Comments were requested on the proposed development of a 35-mm single-frame, time-lapse camera that could be used for such purposes as recording instrument indications. Although the largest percentage of replies covered in Table 26 were noncommittal, the author feels that a need is definitely indicated because the 37% who expressed interest included the largest users of photographic instrumentation. In general, they are governmental agencies, aircraft companies, research foundations and universities whose work calls for storage and later reading of large quantities of instrument data. To further substantiate these views, it is important to know that 5 replies from interested groups (4.9% of the total) have need for a 16-mm single-frame, time-lapse camera.

One user suggested a time-lapse rate from 1 frame every 5 sec to 16 frames/sec.

PROPOSED 35-MM FULL-FRAME HIGH-SPEED CAMERA

Table 27 shows that 30 users were interested in the future development of a 35-mm full-frame, high-speed motion picture camera. The current 35-mm Fastax camera produces an image one-half standard frame height. Increased vertical acceptance angle and elimination of special projection means are behind this interest in a full-frame high-speed camera.

The two replies indicating that such cameras are already in use refer to the General Radio-Camera used with stroboscopic illumination. There appears to be a definite but small need for the proposed development.

USERS' COMMENTS

The returned questionnaires carried comments on many phases of high-speed photography and other techniques of photographic in-

strumentation. Many, in paraphrased form, have been included in the preceding paragraphs; one most often repeated, and one which appears to be of extreme importance, is the request for more information on all phases of high-speed motion picture photography. Many expressed their willingness to co-operate in interchanging experience.

Camera Development

Frame frequency and film capacity requirements have been discussed previously, while other characteristics suggested for further attention follow.

Many requests called for development of optical systems for high-speed cameras capable of markedly higher resolution than is currently possible with the Eastman and Fastax cameras. This is considered to be the most important camera development problem.

Minimizing the period of acceleration was suggested by many, as were general improvements in resolution, wider assortment of lens focal lengths, faster lenses and better focusing systems.

One laboratory, interested in the study of flame propagation phenomena, requires a camera capable of taking a group of 6 to 10 frames at 10^6 frames/sec, and providing for a minimum light loss in the optical and shutter systems.

Many of the users who reported requirements for increased frame frequencies also were concerned with shorter exposure durations per frame. Interest was expressed in the development of repetitive light sources capable of effective exposure durations per frame of 10^{-6} to 10^{-7} sec, and in the development of Kerr cell and focal plane scanning systems.

A number suggested that current prism-type cameras be modified to permit easy removal of the prism assembly for adaptation to stroboscopic and oscillographic recording. It was further suggested that the manufacturer furnish contactors for synchronization of stroboscopic illumination at various frequencies. Another group requested that a slating device for code marking the beginning and end of each run be built into the camera. A built-in voltmeter to permit check of extension line voltage drop was suggested for low-voltage and low-speed operation.

One user suggested development of a composite intermittent and continuously moving film camera, *i.e.*, removable intermittent, using 70-mm film in short lengths or up to 2,000 ft; but frame frequency range was not mentioned.

Development of a drum-type camera to carry 3 ft to 5 ft of film was also suggested. It would be provided with means for event synchronization and for timing correlation with oscillographic recordings.

Accessory Equipment and Process Development

One research group asked for development of a rigid mount for the Fastax cameras which would permit photography with no image vibration when the object is 8 ft from the camera. It should be equipped with a tilt top and micrometer adjustments. Another group felt that a good, portable tripod for getting into small places was desirable.

One laboratory suggested development of an improved timing device to operate at 1,000 cycles/sec. Better timing indications were thought important by several users. Still another requirement felt to be of particular importance calls for better methods for event synchronization.

An interesting medical study requires high-speed photography of normal human vocal cords in the production of sound, the study of the muscles which influence this action, the recording of endolaryngeal structures before and after vocal cord surgery, particularly those with pathology causing hoarseness, and the photography of the cervical end of the esophagus in laryngectomized patients. Interest was expressed here in the recording of sound synchronized with the high-speed motion picture record.

A step-printer was suggested for development to provide a means for the reduction of data from high-speed photography.

Illumination and Illuminants

A number of comments concerning the development of light sources were received:

(1) One concerned development of a system to permit increase of illumination intensity during the film acceleration.

(2) Development was recommended of stroboscopic sources of 1 microsecond duration or shorter, synchronized with a camera, and capable of illuminating an area of 3 ft $\times$ 4 ft.

(3) A brilliant point source of 10^{-7} second duration was felt necessary on a particular research project.

(4) Development of a concentrated light source for photography through lens extension tubes was suggested.

(5) Another concerned a more intense light source to permit use of smaller apertures with resulting greater depth of field.

(6) Experiments with a 100-w, 6-v light source built into a centrifuge for the study of action in a capillary tube were reported. Results looked hopeful, but this researcher was especially interested in learning about reports of "any work ever done anywhere in a centrifuge."

Need was expressed for a remotely controlled, normal-speed, 16-mm camera operating at frame frequencies up to 200 per sec. Accurate view finder and focusing control together with 400-ft film capacity were also requested.

A number suggested development of still and continuously moving film cameras for cathode-ray tube photography.

Many comments related to the wide utility of high-speed motion picture photography in scientific research and engineering research. It was stated to be the only data-recording method capable of providing information in a large number of investigations. Several emphasized its usefulness in engineering education and in training of nontechnical personnel.

A number thought the Committee was an excellent medium for the interchange of knowledge and affirmed their interest in co-operating in its work.

Analysis and Conclusions

Each application of high-speed motion picture photography must be treated as an individual problem. Each requires some element of practice which differs from almost every other use. Thus, any conclusions about what constitutes "standard practice" must be tempered by one's own requirements and practices.

This survey deals essentially with use of the Eastman and Fastax cameras. The manufacturers indicate that those reporting own nearly one-quarter (actually 23.2%) of the cameras extant. Ordinarily, this sampling would be considered adequate. However, 53% of this one-quarter are in the hands of only seven organizations. These are government laboratories which appear to use high-speed photography to a greater extent per camera than do the others. Because there are no frequency of use data currently available, the reader may speculate whether or not this survey reflects accurately the over-all usage picture.

The data in this report are to be evaluated in the light of a partial

picture of the relatively low frame frequency phase of high-speed motion picture photography, that as practiced with the Eastman and Fastax cameras by a small percentage of total users.

The cross-section of the users seems representative and so the author considers that some basic conclusions to be drawn from the data are valid.

Availability of Information

In studying the answers and comments, the author sensed a lack of knowledge about the availability of specialized techniques, cameras and accessory equipment, their characteristics and their limitations. A good portion of equipment suggested for development actually exists in the commercial market. This condition is considered to result, in general, from the relatively undeveloped state of the art, and in particular from the poor exchange of knowledge on all phases of the subject. Many recognized the problem and issued an urgent plea for more information concerning high-speed practices. From his own observations in the very recent past in connection with a Navy-sponsored project, the author cannot over-emphasize this vast and highly important requirement.

Photographic instrumentation is used in virtually all branches of science and engineering. Its practitioners are spread widely and, incidentally, thinly, among the several arts, making difficult the interchange of information. Technical papers delivered before one professional group find slow distribution to other groups in different fields. Finding this information is a most difficult task, for it is spread among an enormous number of technical journals, domestic and foreign. It is difficult to recognize readily articles of interest, for instrumentation itself is only rarely the subject of the article. Publishers have had to limit the length of technical papers, so that much instrumentation data have been presented briefly, if at all.

Many of those reporting requested information about the Society, indicating limited awareness of the Committee and its functions, but indicating also that the Society is being looked to as an important source of technical information on high-speed motion picture photography and related arts. A program sponsored by the Committee is under way for better distribution of information. It should be expanded.

A brief analysis of the survey results follows and is organized by specific subjects.

The survey data on lenses and field sizes seems to present an accurate summation of current practice based upon the characteristics of the lenses now available. Because so many report using their lenses wide open, a lighting problem is shown to exist.

The illumination data reflect practices prior to general availability of the G.E. 750R lamp which is likely to be adapted by those who were accustomed to overvolting reflector spots and floods.

It was somewhat surprising that so relatively few reported the use of professional motion picture incandescent and carbon arc lighting equipment. Once again, the users' comments indicate that some are not aware of the existence of many of the available illuminants which might easily satisfy some of the expressed requirements.

Producing adequate light intensities, however, still poses one of the most serious problems. In some cases, an additional requirement for special spectral distribution exists. While considerable effort is being put into development of light sources not necessarily photographic, much additional work is required.

Film data and comments furnish ground for research leading to improved illumination and resolution characteristics of high-speed cameras.

It is felt that a considerable requirement lies in the rapid negative and reversal processing of high-speed records. Local professional motion picture processing facilities are not generally known to the high-speed photographic practitioner. More extensive use of such facilities may prove of value. Failing such local availability, and this is most often the case, a rapid means for development and also for printing is considered essential. In many investigations, it is vital that the records be studied or measured immediately after exposure. In general, this is not possible. In fact, one of the major deterrents to the use of photographic instrumentation is the time lost between exposure and examination. This problem must be solved before wider utilization of the photographic method is possible or feasible.

The data on frame frequencies used are quite as expected. The frequency range is fixed by the camera design, while the particular frequency used is established by the nature of the phenomenon under investigation.

The requirement expressed for increased frame frequency is considered significant, and while there are a number of domestic and foreign cameras commercially available that can operate in some of the ranges desired, more information concerning frame frequency,

resolution, exposure duration per frame and other characteristics should be published.

The writer is essentially in agreement with the opinion that present film capacity is greater than necessary, especially in quantitative applications. The fundamental problem is one of precise event synchronization. More information on this subject was requested and should be developed.

There are numerous phenomena which can be studied only over a relatively long period of time. In such instances, action may be covered satisfactorily by such expedients as timing several cameras to operate in succession. But there are many special cases where this is not feasible; therefore, a possible requirement for additional film capacity does exist.

Then there is that 44½-mile magazine! There will be a rush for film manufacturing companies' stock when it is developed!

The author expected a greater response than was expressed for the 35-mm single-frame, time-lapse camera. Nonetheless, it is evident that an important requirement exists.

The current 35-mm Fastax produces a frame one-half standard height by standard frame width leading to the suggestion that a full-frame camera, presumably of the same type (*i.e.*, rotating prism, continuously moving film) should be developed. Some expressed the feeling that such a camera must also be capable of higher resolution not necessarily implied by increased frame size.

Those using General Radio cameras (continuously moving film in conjunction with intermittent discharge light sources) felt that they possessed a camera such as proposed. However, frame frequency range is limited to 1,500 per sec for full frame height. Resolution of the resulting film record is high, provided the following ratio is small: Effective exposure duration per frame (t_e) divided by the reciprocal of the frame frequency (t_f).

Development of a full-frame camera with operating characteristics exceeding those of General Radio camera is considered important. Among these characteristics are higher frame frequency, and possibly the ability to photograph subjects in direct illumination (or self-luminous bodies) not possible with stroboscopic illumination systems.

One of the most important requirements, noted briefly by one user, lies in the techniques of data reduction. Rapid and accurate means are becoming increasingly important.

RECOMMENDATIONS

A number of additional recommendations, based primarily upon information brought to light in this survey but corroborated by the Navy study previously referred to,* are respectfully submitted to the Committee and to the membership at large.

Increased Scope of the Committee's Interest

The Society's scope of interest has been said to lie in those fields, the common denominator of which is "film." The Committee, in the same regard, should be concerned with all photographic instrumentation, covering its use in science and engineering for detection, recording, and measurement.† To do so will require active participation of many other professional agencies and societies.

Interchange of Information

A four-point program for the improvement of the interchange of technical information is recommended.

(1) Publicize the Committee and its functions.
(2) Establish effective liaison throughout all science and engineering.
(3) Encourage the greater production of technical papers.
(4) Establish wider presentation and dissemination of technical papers.

In order to implement such a program, the following procedures are suggested.

Effective liaison and active co-operation should be established with technical and professional societies having an interest in photographic instrumentation.‡ A panel might be set up of representatives of societies, such as those suggested in the following list, whose function it would be to keep their own groups fully informed and to inform the Committee of developments in photographic instrumentation of mutual interest.

* At present, this information is classified, but it is hoped that it will be released in the near future. The work was carried out under the auspices of the Office of Naval Research.

† The Committee has increased its scope in accordance with this recommendation and has changed its name to "The High-Speed and Technical Photography Committee"—January, 1950.

‡ The committee has established its "Technical and Scientific Society Liaison Subcommittee" to carry out this recommendation—January, 1950.

Acoustical Soc. of Am.
Am. Chemical Soc.
Am. Inst. of Chemical Engr.
Am. Inst. of Electrical Engr.
Am. Inst. of Physics
Am. Microscopical Soc.
Am. Physical Soc.
Am. Rocket Soc.
Am. Soc. Heating and Ventilating Engr.
Am. Soc. of Mechanical Engr.
Am. Soc. for Metals
Am. Soc. of Photogrammetry
Am. Soc. for Testing Materials
Am. Soc., X-ray and Elec. Diffraction
Am. Welding Soc.
Biological Photographic Assn.
Electron Microscope Soc. of Am.
Illuminating Eng. Soc.
Industrial Management Soc.
Inst. of Aeronautical Sciences
Inst. of Radio Engr.
Instrument Soc. of Am.
Optical Soc. of Am.
Royal Photographic Soc. (Gr. Br.)
Soc. of Automotive Engr.
Soc. for Adv. of Management
Soc. for Applied Spectroscopy
Soc. for Experimental Stress Analysis
Soc. for Non-Destructive Testing
Soc. of Photographic Engr.

In this way, a greater awareness of the Committee's work will be achieved, effective liaison with all branches of science and engineering will be established as suggested and a more effective channel for the presentation and dissemination of information will be achieved.

This liaison should greatly increase technical paper preparation. It will give workers an opportunity to report upon the details and application of photographic instrumentation not currently possible elsewhere.

Manufacturers of equipment should be encouraged to prepare comprehensive papers concerning their products. It is suggested that a standard outline be adopted so that an equipment digest containing all this material may be prepared, with some means established to keep the information current.

Papers should be invited from the leading proponents of photographic instrumentation and users should be encouraged to contribute papers concerning applications. The inter-society co-operation suggested should endeavor to accelerate this technical papers program.

It is suggested that the symposia currently held semi-annually in conjunction with the Society conventions be extended to local meetings more often and in additional localities.

Continuation and expansion of the publication of special supplements to the Society's JOURNAL containing papers on photographic instrumentation are suggested. Perhaps an A and B edition will one day result, comparable to the General and Technical Sections of the *Journal of the Royal Photographic Society*.

It is felt that one of the most important additions to the scientific literature on the subject of photographic instrumentation would be a monthly digest or review (not an abstract) publication patterned

after the admirable French *Science et Industries Photographiques* of M. Louis P. Clerc, containing condensed, concise, illustrated versions of the scientific and engineering literature, both domestic and foreign, of interest to photographic instrumentation. Comprehensive indexing and cross-referencing of this sort of material would aid measurably in determining the prior state of any phase of the art.

Continued Surveys

It is recommended that a program be established to survey comprehensively photographic instrumentation by each of its phases; *e.g.*, illuminants, reduction of data, event synchronization, Schlieren photography, etc.

A Subcommittee on Standards and Definitions

Formation of a subcommittee on Standards and Definitions for Photographic Instrumentation is suggested. In the case of every new scientific field, there has been required a meeting of the minds on definitions and the standards and standard measurement methods necessary for such definitions. It has become increasingly important to define many of these terms on a universally understood basis. Among those terms suggested for definition and for the establishment of standards to support them for high-speed motion picture photography are:

(1) *Effective aperture.*

(2) *Effective exposure duration per frame.*

(3) *Effective flash duration for single- and multiple-flash transient sources*, such as spark gaps, gaseous discharge tubes, and the like.

(4) *Frame frequency categories.* The need for a more concrete basis for the establishment of a frame frequency spectrum to make easier the scientific discussion of high-speed motion picture photography is recommended by the author. He and his colleagues have adopted radio frequency designations and have given definition to "normal speed," "high-speed," "very high-speed" and "ultra-high-speed" photography. Table 23 uses these categories. (See discussion under Frame Frequencies, above.)

ACKNOWLEDGMENTS

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Constitution of the Society of Motion Picture and Television Engineers

ARTICLE I

NAME

The name of this association shall be SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS.

ARTICLE II

OBJECTS

Its objects shall be: Advancement in the theory and practice of engineering in motion pictures, television, and the allied arts and sciences; the standardization of equipment and practices employed therein; the maintenance of a high professional standing among its members; and the dissemination of scientific knowledge by publication.

ARTICLE III

MEETINGS

There shall be an annual meeting and such other regular and special meetings as provided in the Bylaws.

ARTICLE IV

ELIGIBILITY FOR MEMBERSHIP

Any person of good character is eligible to become a member in any grade for which he is qualified in accordance with the Bylaws.

ARTICLE V

OFFICERS

The officers of the Society shall be a President, an Executive Vice-President, a Past-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of all elected officers shall be for a period of two years.

The President shall not be eligible to succeed himself in office.

At the conclusion of his term of office the President automatically becomes Past-President.

Under conditions as set forth in the Bylaws, the office of Executive Vice-President may be vacated before the expiration of his term.

A vacancy in any office shall be filled for the unexpired portion of the term in accordance with the Bylaws.

ARTICLE VI

SECTIONS

Sections may be established in accordance with the Bylaws.

ARTICLE VII

BOARD OF GOVERNORS

The Board of Governors shall consist of the President, the Past-President, the five Vice-Presidents, the Secretary, the Treasurer, the Section Chairmen, and twelve elected Governors. An equal number of these elected Governors shall reside within the areas included in the Eastern time zone; the Central time zone; and the Pacific and Mountain time zones. The term of office of all elected Governors shall be for a period of two years.

ARTICLE VIII

AMENDMENTS

This Constitution may be amended as follows: Amendments may originate as recommendations within the Board of Governors, or as a proposal to the Board of Governors, by any ten members of voting grade; when approved by the Board of Governors as set forth in the Bylaws, the proposed amendment shall then be submitted for discussion at the annual meeting or at a regular or special meeting called as provided in the Bylaws. The proposed amendment, together with the discussion thereon, shall then be promptly submitted by mail to all members qualified to vote, as set forth in the Bylaws. Voting shall be by letter ballot mailed with the proposed amendment and discussion to the voting membership. In order to be counted, returned ballots must be received within sixty (60) days of the mailing-out date. An affirmative vote of two thirds of the valid ballots returned, subject to the above time limitations, shall be required to carry the amendment, provided one fifteenth of the duly qualified members shall have voted within the time limit specified herein.

BYLAWS OF THE SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

BYLAW I

MEMBERSHIP

Sec. 1. Membership of the Society shall consist of the following grades: Honorary members, Sustaining members, Fellows, Active members, Associate members and Student members.

An *Honorary member* is one who has performed eminent service in the advancement of engineering in motion pictures, television, or allied arts. An Honorary member shall be entitled to vote and to hold any office in the Society.

A *Sustaining member* is an individual, company, or corporation subscribing substantially to the financial support of the Society.

A *Fellow* is one who shall be not less than thirty years of age and who shall by his proficiency and contributions have attained to an outstanding rank among engineers or executives of the motion picture or television industries. A Fellow shall be entitled to vote and to hold any office in the Society.

An *Active member* is one who shall be not less than twenty-five years of age and shall be or shall have been either one or an equivalent combination of the following:

(a) An engineer or scientist in motion picture, television or allied arts. As such he shall have performed and taken responsibility for important engineering or scientific work in these arts and shall have been in the active practice of his profession for at least three years, or

(b) A teacher of motion picture, television or allied subjects for at least six years in a school of recognized standing in which he shall have been conducting a major course in at least one of such fields, or

(c) A person who by invention or by contribution to the advancement of engineering or science in motion picture, television or allied arts, or to the technical literature thereof, has attained a standing equivalent to that required for Active membership in (a), or

(d) An executive who for at least three years has had under his direction important engineering or responsible work in the motion picture, television or allied industries and who is qualified for direct supervision of the technical or scientific features of such activities. An Active member shall be entitled to vote and to hold any office in the Society.

An *Associate member* is one who shall be not less than eighteen years of age, and shall be a person who is interested in the study of motion picture or television technical problems or connected with the application of them. An Associate member is not privileged to vote, to hold office or to act as chairman of any committee, although he may serve upon any committee to which he may be appointed; and, when so appointed, shall be entitled to the full voting privileges on action taken by the committee.

A *Student member* is any person registered as a student, graduate or undergraduate, in a college, university, or other educational institution of like scholastic standing, who evidences interest in motion picture or television technology. Membership in this grade shall not extend more than one year beyond the termination of the student status described above. A student member shall have the same privileges as an Associate member of the Society.

Sec. 2. All applications for membership or transfer should be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow grades may not be applied for.

Sec. 3. (a) Honorary membership may be granted upon recommendation of the Honorary Membership Committee when confirmed first by a three-fourths majority vote of those present at a meeting of the Board of Governors, and then by a four-fifths majority vote of all voting members present at any regular meeting or at a special meeting called as stated in the bylaws. An Honorary member shall be exempt from the payment of all dues.

(b) Upon recommendation of the Fellow Award Committee, when confirmed by a three-fourths majority vote by those present at a meeting of the Board of Governors, an Active member may be made a Fellow.

(c) An Applicant for Active membership shall give as references at least two mem-

bers of the grade applied for or of a higher grade. Applicants shall be elected to membership by a three-fourths majority vote of the entire membership of the appropriate Admissions Committee. An applicant may appeal to the Board of Governors if not satisfied with the action of the Admissions Committee, in which case approval of at least three-fourths of those present at a meeting of the Board of Governors shall be required for election to membership or to change the action taken by the Admissions Committee.

(d) An applicant for Associate membership shall give as reference one member of the Society, or two persons not members of the Society who are associated with the motion picture, television, or allied industry. Applicants shall be elected to membership by approval of the Chairman of the appropriate Admissions Committee.

(e) An applicant for Student membership shall be sponsored by a member of the Society, or by a member of the staff of the department of the institution he is attending, this faculty member not necessarily being a member of the Society. Applicants shall be elected to membership by approval of the Chairman of the appropriate admissions committee.

Sec. 4. Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors, provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

BYLAW II

OFFICERS

Sec. 1. An officer or governor shall be an Honorary member, Fellow, or an Active member.

BYLAW III

BOARD OF GOVERNORS

Sec. 1. The Board of Governors shall transact the business of the Society in accordance with the Constitution and Bylaws.

Sec. 2. The Board of Governors may act on special resolutions between meetings, by letter ballot authorized by the President. An affirmative vote from a majority of the total membership of the Board of Governors shall be required for approval of such resolutions.

Sec. 3. A quorum of ten members of the Board of Governors shall be present to vote on resolutions presented at any meeting. Unless otherwise specified, a majority vote of the Governors present shall constitute approval of a resolution.

Sec. 4. A member of the Board of Governors may not authorize an alternate to act or vote in his stead.

Sec. 5. Vacancies in the offices or on the Board of Governors shall be filled by the Board of Governors until the annual elections of the Society.

Sec. 6. The Board of Governors, when filling vacancies in the offices or on the Board of Governors, shall endeavor to appoint persons who in the aggregate are representative of the various branches or organizations of the industries interested in the activities of the Society to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of such industries.

Sec. 7. The time and place of all except special meetings of the Board of Governors shall be determined by the Board of Governors.

Sec. 8. Special Meetings of the Board of Governors shall be called by the President with the proviso that no meeting shall be called without at least seven days prior notice to all members of the Board by letter or telegram. Such a notice shall state the purpose of the meeting.

BYLAW IV

ADMINISTRATIVE PRACTICES

Sec. 1. Special rules relating to the administration of the Society and known as Administrative Practices shall be established by the Board of Governors and shall be added to or revised as necessary to the efficient pursuit of the Society's objectives.

BYLAW V

COMMITTEES

Sec. 1. All committees, except as otherwise specified, shall be formed and appointed in accordance with the Administrative Practices as determined by the Board of Governors.

Sec. 2. All committees, except as otherwise specified, shall be appointed to act for the term served by the officer charged with appointing the committees or until he terminates the appointment.

Sec. 3. Chairmen of the committees shall not be eligible to serve in such capacity for more than two consecutive terms.

Sec. 4. Standing Committees of the Society to be appointed by the President and confirmed by the Board of Governors are as follows:

Honorary Membership Committee
Journal Award Committee
Nominating Committee
Progress Medal Award Committee
Public Relations Committee
Samuel L. Warner Memorial Award Committee

Sec. 5. There shall be an Admissions Committee for each Section of the Society composed of a chairman and three members of which at least two shall be members of the Board of Governors.

Sec. 6. There shall be a Fellow Award Committee composed of all the officers and section chairmen of the Society under the chairmanship of the Past-President. In case the chairmanship is vacated it shall be temporarily filled by appointment by the President.

BYLAW VI

MEETINGS OF THE SOCIETY

Sec. 1. The location and time of each meeting or convention of the Society shall be determined by the Board of Governors.

Sec. 2. The grades of membership entitled to vote are defined in Bylaw I.

Sec. 3. A quorum of the Society shall consist in number of $\frac{1}{15}$ of the total of those qualified to vote as listed in the Society's records at the close of the last fiscal year before the meeting.

Sec. 4. The annual meeting shall be held during the fall convention.

Sec. 5. Special meetings may be called by the President and upon the request of any three members of the Board of Governors not including the President.

Sec. 6. All members of the Society in any grade shall have the privilege of discussing technical material presented before the Society or its Sections.

BYLAW VII

DUTIES OF OFFICERS

Sec. 1. The President shall preside at all business meetings of the Society and shall perform the duties pertaining to that office. As such he shall be the chief executive of the Society, to whom all other officers shall report.

Sec. 2. In the absence of the President, the officer next in order as listed in Article V of the Constitution shall preside at meetings and perform the duties of the President.

Sec. 3. The seven officers shall perform the duties separately enumerated below and those defined by the President:

(a) The Executive Vice-President shall represent the President, and shall be responsible for the supervision of the general affairs of the Society as directed by the President.

The President and the Executive Vice-President shall not both reside in the geographical area of the same Society Section, but one of these officers shall reside in the vicinity of the executive offices. Should the President or Executive Vice-President remove his residence to the same geographical area of the United States as the other, the office of Executive Vice-President shall immediately become vacant and a new Executive Vice-President shall be elected by the Board of Governors for the unexpired portion of the term.

(b) The Engineering Vice-President shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and co-ordination of the work of these committees.

(c) The Editorial Vice-President shall be responsible for the publication of the Society's *Journal* and all other Society publications.

(d) The Financial Vice-President shall be responsible for the financial operations of the Society, and shall conduct them in accordance with budgets prepared by him and approved by the Board of Governors.

(e) The Convention Vice-President shall be responsible for the national conventions of the Society. He shall arrange for at least one annual convention to be held in the fall of the year.

Sec. 4. The Secretary shall keep a record of all meetings; and shall have the responsibility for the care and custody of records, and the seal of the Society.

Sec. 5. The Treasurer shall have charge of the funds of the Society and disburse them as and when authorized by the Financial Vice-President. He shall be bonded in an amount to be determined by the Board of Governors, and his bond shall be filed with the Secretary.

Sec. 6. Each officer of the Society, upon the expiration of his term of office, shall

transmit to his successor a memorandum outlining the duties and policies of his office.

BYLAW VIII

SOCIETY ELECTIONS

Sec. 1. All officers and governors shall be elected to their respective offices by a majority of ballots cast by voting members in the following manner:

Nominations shall first be presented by a Nominating Committee appointed by the President, consisting of nine members, including a Chairman. The committee shall be made up of two Past-Presidents, three members of the Board of Governors not up for election, and four other voting members, not currently officers or governors of the Society. Nominations shall be made by three-quarters affirmative vote of the total Nominating Committee.

Not less than three months prior to the Annual Fall Meeting, the Board of Governors shall review the recommendations of the Nominating Committee, which shall have nominated suitable candidates for each vacancy.

Such nominations shall be final unless any nominee is rejected by a three-quarters vote of the Board of Governors present and voting. The Secretary shall then notify these candidates of their nomination. From the list of acceptances, not more than three names for each vacancy shall be selected by the Board of Governors and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the name of any voting member other than those suggested by the Board of Governors may be voted for. The balloting shall then take place. The ballot shall be enclosed with a blank envelope and a business reply envelope bearing the Secretary's address and a space for the member's name and address. One set of these shall be mailed to each voting member of the Society, not less than forty days in advance of the annual fall meeting.

The voter shall then indicate on the ballot one choice for each vacancy, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention.

The sealed envelope shall be delivered by the Secretary to a Committee of Tellers appointed by the President at the annual fall convention. This committee shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly-elected officers and governors of the Society shall take office on January 1, following their election.

BYLAW IX

DUES AND INDEBTEDNESS

Sec. 1. The annual dues shall be fifteen dollars ($15) for Fellows and Active members, ten dollars ($10) for Associate members, and five dollars ($5) for Student members, payable on or before January 1, of each year. Current or first year's dues for new members in any calendar year shall be at the full annual rate for those notified of election to membership on or before June 30; one half the annual rate for those notified of election to membership in the Society on or after July 1.

Sec. 2. (a) Transfer of membership to a higher grade may be made at any time subject to the requirements for initial membership in the higher grade. If the transfer is made on or before June 30, the annual dues of the higher grade are required. If the transfer is made on or after July 1, and the member's dues for the full year have been paid, one half of the annual dues of the higher grade is payable less one half the annual dues of the lower grade.

(b) No credit shall be given for annual dues in a membership transfer from a higher to a lower grade, and such transfers shall take place on January 1, of each year.

Sec. 3. Annual dues shall be paid in advance.

Sec. 4. Failure to pay dues may be considered just cause for suspension.

BYLAW X

PUBLICATIONS

Sec. 1. The Society shall publish a technical magazine to consist of twelve monthly issues, in two volumes per year. The editorial policy of the *Journal* shall be based upon the provisions of the Constitution and a copy of each issue shall be supplied to each member in good standing mailed to his last address of record.

Copies may be made available for sale at a price approved by the Board of Governors.

BYLAW XI

LOCAL SECTIONS

Sec. 1. Sections of the Society may be authorized in any locality where the voting membership exceeds twenty. The geographic boundaries of each Section shall be determined by the Board of Governors. Upon written petition for the authorization of a Section of the Society, signed by twenty or more voting members, the Board of Governors may grant such authorization.

SECTION MEMBERSHIP

Sec. 2. All members of the Society of the Motion Picture and Television Engineers in good standing residing within the geographic boundaries of any local Section shall be considered members of that Section.

Sec. 3. Should the enrolled voting membership of a Section fall below twenty, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining that Section, the Board of Governors may cancel its authorization.

SECTION OFFICERS

Sec. 4. The officers of each Section shall be a Chairman and a Secretary-Treasurer. The Section chairmen shall be ex-officio members of the Board of Governors and shall continue in such positions for the duration of their terms as chairmen of the local Sections. Each Section officer shall hold office for one year, or until his successor is chosen.

SECTION BOARD OF MANAGERS

Sec. 5. The Board of Managers shall consist of the Section Chairman, the Section Past-Chairman, the Section Secretary-Treasurer, and six voting members. Each manager of a Section shall hold office for two years. Vacancies shall be filled by appointment by the Board of Managers until the annual election of the Section.

SECTION ELECTIONS

Sec. 6. The officers and managers of a Section shall be voting members of the Society. All officers and managers shall be elected to their respective offices by a majority of ballots cast by the voting members residing in the geographical area of the Section. Not less than three months prior to the annual fall convention of the Society, nominations shall be presented to the Board of Managers of the Section by a Nominating Committee appointed by the Chairman of the Section, consisting of seven members, including a chairman. The committee shall be composed of the present Chairman, the Past-Chairman, two other members of the Board of Managers not up for election, and three other voting members of the Section not currently officers or managers of the Section. Nominations shall be made by a three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final, unless any nominee is rejected by a three-quarters vote of the Board of Managers, and in the event of such rejection the Board of Managers will make its own nomination.

The Chairman of the Section shall then notify the candidates of their nomination. From the list of acceptances, not more than three names for each vacancy shall be selected by the Board of Managers and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the name of any voting member other than those suggested by the Board of Managers may be voted for. The balloting shall then take place. The ballot shall be enclosed with a blank envelope and a business reply envelope bearing the local Secretary-Treasurer's address and a space for the member's name and address. One of these shall be mailed to each voting member of the Society residing in the geographical area covered by the Section, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention. The sealed envelopes shall be delivered by the Secretary-Treasurer to his Board of Managers at a

duly called meeting. The Board of Managers shall then examine the returned envelopes, open and count the ballots, and announce the results of the election.

The newly-elected officers and managers shall take office on January 1, following their election.

SECTION BUSINESS

Sec. 7. The business of a Section shall be conducted by the Board of Managers.

SECTION EXPENSES

Sec. 8. (a) At the beginning of each fiscal year, the Secretary-Treasurer of each section shall submit to the Board of Governors of the Society a budget of expenses for the year.

(b) The Treasurer of the Society shall deposit with each Section Secretary-Treasurer a sum of money for current expenses, the amount to be fixed by the Board of Governors.

(c) The Secretary-Treasurer of each Section shall send to the Treasurer of the Society, quarterly or on demand, an itemized account of all expenditures incurred during the preceding period.

(d) Expenses other than those enumerated in the budget, as approved by the Board of Governors of the Society, shall not be payable from the general funds of the Society without express permission from the Board of Governors.

(e) The Section Board of Managers shall defray all expenses of the Section not provided for by the Board of Governors, from funds raised locally.

(f) The Secretary of the Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

SECTION MEETINGS

Sec. 9. The regular meetings of a Section shall be held in such places and at such hours as the Board of Managers may designate. The Secretary-Treasurer of each Section shall forward to the Secretary of the Society, not later than five days after a meeting of a Section, a statement of the attendance and of the business transacted.

CONSTITUTION AND BYLAWS

Sec. 10. Sections shall abide by the Constitution and Bylaws of the Society and conform to the regulations of the Board of Governors. The conduct of Sections shall always be in conformity with the general policy of the Society as fixed by the Board of Governors.

BYLAW XII

STUDENT CHAPTERS

Sec. 1. Student Chapters of the Society may be authorized in any college, university, or technical institute of collegiate standing. Upon written petition for the authorization of a Student Chapter, signed by twelve or more Society members, or applicants for Society membership, and the Faculty Adviser, the Board of Governors may grant such authorization.

CHAPTER MEMBERSHIP

Sec. 2. All members of the Society in good standing who are attending the designated educational institution shall be eligible for membership in the Student Chapter, and when so enrolled they shall be entitled to all privileges that such Student Chapter may, under the Constitution and Bylaws, provide.

Sec. 3. Should the membership of the Student Chapter fall below ten, or the average attendance at meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

CHAPTER OFFICERS

Sec. 4. The officers of each Student Chapter shall be a Chairman and a Secretary-Treasurer. Each Chapter officer shall hold office for one year, or until his successor is chosen. Where possible, officers shall be chosen in May to take office at the beginning of the following school year. The procedure for holding elections shall be prescribed in Administrative Practices.

FACULTY ADVISER

Sec. 5. A member of the faculty of the same educational institution shall be designated by the Board of Governors as Faculty Adviser. It shall be his duty to advise the officers on the conduct of the Chapter and to approve all reports to the Secretary and the Treasurer of the Society.

CHAPTER EXPENSES

Sec. 6. The Treasurer of the Society shall deposit with each Chapter Secretary-Treasurer a sum of money, the amount to be fixed by the Board of Governors. The Secretary-Treasurer of the Chapter shall send to the Treasurer of the Society at the

end of each school year or on demand an itemized account of all expenditures incurred.

CHAPTER MEETINGS

Sec. 7. The Chapter shall hold at least four meetings per year. The Secretary-Treasurer shall forward to the Secretary of the Society at the end of each school year a report of the meetings for that year, giving the subject, speaker, and approximate attendance for each meeting.

BYLAW XIII

AMENDMENTS

Sec. 1. Proposed amendments to these Bylaws may be initiated by the Board of Governors or by a recommendation to the Board of Governors signed by ten voting members. Proposed amendments may be approved at any regular meeting of the Society at which a quorum is present, by the affirmative vote of two-thirds of the members present and eligible to vote thereon. Such proposed amendments shall have been published in the *Journal* of the Society, in the issue next preceding the date of the stated business meeting of the Society at which the amendment or amendments are to be acted upon.

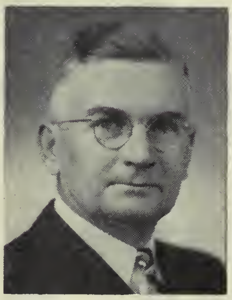
Sec. 2. In the event that no quorum of the voting members is present at the time of the meeting referred to in Sec. 1, the amendment or amendments shall be referred for action to the Board of Governors. The proposed amendment or amendments then become a part of the Bylaws upon receiving the affirmative vote of three-quarters of the entire membership of the Board of Governors.

OFFICERS
OF THE SOCIETY
April, 24, 1950

PETER MOLE
Executive Vice-President
1949–50

EARL I. SPONABLE
President
1949–50

LOREN L. RYDER
Past-President
1949–50



FRED T. BOWDITCH
Engineering Vice-President
1950–51

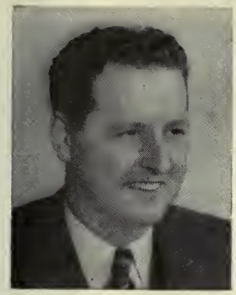
CLYDE R. KEITH
Editorial Vice-President
1949–50

RALPH B. AUSTRIAN
Financial Vice-President
1950–51

WILLIAM C. KUNZMANN
Convention Vice-President
1949–50

ROBERT M. CORBIN
Secretary
1949–50

Frank E. Cahill, Jr.
Treasurer, 1950–51

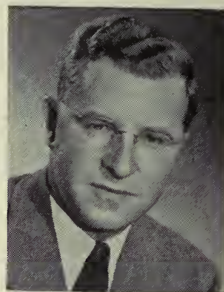


Herbert Barnett
Governor, 1949–50

Kenneth F. Morgan
Governor, 1949–50

Norwood L. Simmons
Governor, 1949–50

J. P. Livadary
Governor, 1950



William B. Lodge
Governor, 1950

Lorin D. Grignon
Governor, 1950–51

Paul J. Larsen
Governor, 1950–51

William H. Rivers
Governor, 1950–51

R. T. Van Niman
Governor, 1950–51

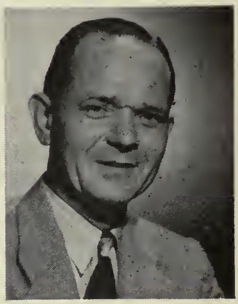
Edward S. Seeley
Governor, 1950–51

MALCOLM G. TOWNSLEY
Governor, 1950

FRANK E. CARLSON
Governor, 1950

EDWARD SCHMIDT
Governor, 1950

GEORGE W. COLBURN
Governor, 1950



CHARLES R. DAILY
Governor, 1950

OFFICERS AND MANAGERS OF SECTIONS

ATLANTIC COAST: Chairman, Edward Schmidt; *Secretary-Treasurer,* H. C. Milholland; *Managers,* E. A. Bertram, E. Dudley Goodale, R. G. Mann, Pierre Mertz, R. E. Shelby, E. M. Stifle

CENTRAL: Chairman, G. W. Colburn; *Secretary-Treasurer,* C. E. Heppberger; *Managers,* F. E. Carlson, E. W. D'Arcy, R. E. Lewis, A. Shapiro, Lloyd Thompson, M. G. Townsley

PACIFIC COAST: Chairman, C. R. Daily; *Secretary-Treasurer,* Vaughn Shaner; *Managers,* Larry Aicholtz, G. M. Best, L. D. Grignon, J. P. Livadary, Roy Monfort, E. H. Reichard

STUDENT CHAPTER OFFICERS

NEW YORK UNIVERSITY: Chairman, William F. Boden; *Secretary-Treasurer,* Gerald I. Rosenfeld

UNIVERSITY OF SOUTHERN CALIFORNIA: Chairman, Melvin R. Kells; *Secretary-Treasurer,* Eric T. Sjolander

WILLIAM F. BODEN
Chairman,
New York University

MELVIN R. KELLS
Chairman, University of
Southern California

TREASURER'S REPORT

January 1—December 31, 1949

Cash		
Cash on Deposit, Chase National Bank, January 1, 1949	$6,483.68	
Net Receipts	(352.24)	
Cash on Deposit, Chase National Bank, December 31, 1949		$6,131.44
Petty Cash Fund		200.00
Total Cash on Hand and in Bank		6,331.44
Investments		
Savings Accounts, January 1, 1949	$15,193.75	
Add: Interest Credited	510.61	
Savings Accounts, December 31, 1949	$15,704.36	
U. S. Government Bonds (at cost)	60,000.00	
Total Investments		75,704.36
Total Cash and Investments, December 31, 1949		$82,035.80

Respectfully submitted,
RALPH B. AUSTRIAN, Treasurer

SUMMARY OF FINANCIAL CONDITION

December 31, 1949

Assets (What Your Society Owns)	
Cash on Hand and in Bank	$ 6,331.44
Savings Accounts	15,704.36
U. S. Government Bonds (at cost)	60,000.00
Accounts Receivable	9,717.29
Book Inventory	1,000.00
Test Film Inventory	3,304.41
Test Film Equipment (depreciated value)	7,461.71
Office Furniture and Equipment (memo value)	1.00
Total Assets	$103,520.21
Liabilities (What Your Society Owes)	
Accounts Payable	$ 1,399.97
Customers Payments Received in Advance	984.93
Membership Dues Received in Advance	8,810.03
New York City Sales Tax Payable	13.27
Reserve for 1950 Five Year Index	2,000.00
Total Liabilities	$ 13,208.20
Members' Equity (What Your Society Is Worth)	$ 90,312.01
Total Liabilities and Members' Equity	$103,520.21

STATEMENT OF INCOME AND EXPENSES

January 1—December 31, 1949

Test Film Operations		
Total Test Film Sales	$37,166.64	
Cost of Test Films Sold	23,384.25	
Net Income from Test Film Operations		$13,782.39
Publications Operations		
Total Publications Income	$21,222.97	
Net Cost of Publications	41,668.27	
Net Loss from Publications Operations		(20,445.30)
Other Operations		
Total Income from Other Operations	$ 571.20	
Cost of Other Operations	344.60	
Net Income from Other Operations		226.60
Other Income		
Membership Dues	$57,046.45	
Interest Earned	1,961.86	
Total Other Income		59,008.31
Total Operating Income		$52,572.00
Operating Expenses		
Engineering	$10,249.52	
Non-Engineering	2,029.82	
General Office and Administrative	38,752.50	
Officers	171.65	
Sections	2,275.00	
SMPE Affiliations	1,100.00	
Conventions (Net)	299.46	
Total Operating Expenses		54,877.95
Net Operating Loss		$(2,305.95)
Other Deductions		
Depreciation of Test Film Equipment	$ 3,730.86	
Provision for 1950 Five Year Index	500.00	
Total Other Deductions		4,230.85
Excess of Expenses Over Income		$(6,536.81)

The foregoing financial statements were prepared from the records of the Society for the year 1949 and reflect the results of operations for that year. The records and financial statements were audited for the year ended December 31, 1949, by Sparrow, Waymouth and Company, Certified Public Accountants, New York City, and are in conformity with that audit.

D. B. Joy, Financial Vice-President

MEMBERSHIP REPORT

For Year Ended December 31, 1949

	Hon.	Sust.	Fel.	Act.	Assoc.	Stud.	Total
Membership, January 1, 1949...	4	70	178	734	1760	154	2900
New Members............		4		185	283	108	580
Reinstatements...........				10	12	2	24
	4	74	178	929	2055	264	3504
Resignations..............	−2	−7		−8	−38	−3	−58
Deceased.................			−2	−5	−8		−15
Delinquents...............			−3	−56	−193	−32	−284
	2	67	173	860	1816	229	3147
Changes in Grade:							
Active to Fellow.........			14	−14			
Associate to Active.......				24	−24		
Student to Active........				2		−2	
Active to Associate.......				−1	1		
Student to Associate.....					7	−7	
Membership, December 31, 1949..	2	67	187	871	1800	220	3147

NONMEMBER SUBSCRIPTION REPORT

For Year Ended December 31, 1949

Subscriptions, January 1, 1949..................	767
New Subscriptions............................	376
	1143
Cutoffs and Expirations........................	645
Subscriptions, December 31, 1949................	488

Meetings of Other Societies

Acoustical Society of America, Spring Meeting, June 22–24, State College, Pa.

Illuminating Engineering Society, National Technical Conference, Aug. 21–25, Pasadena, Calif.

Biological Photographic Assn., Annual Meeting, Sept. 6–8, Hotel Sheraton, Chicago

Institute of Radio Engineers, West Coast Convention, Sept. 13–15, Long Beach, Calif.

Audio Engineering Society, National Convention, Oct. 26–28, Hotel New Yorker, New York

Optical Society of America, Oct. 26–28, New York, N.Y.

Acoustical Society of America, Fall Meeting, Nov. 9–11, Boston, Mass.

Awards

In accordance with the provisions of the Administrative Practices of the Society and the regulations for granting the Journal Award, the Progress Medal Award and the Samuel L. Warner Memorial Award, a list of names of previous recipients, and the reasons therefor are published annually in the Journal as follows:

JOURNAL AWARD

The Journal Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

At the fall convention of the Society a Journal Award Certificate shall be presented to the author or to each of the authors of the most outstanding paper originally published in the Journal of the Society during the preceding calendar year.

Other papers published in the Journal of the Society may be cited for Honorable Mention at the option of the Committee, but in any case should not exceed five in number.

The Journal Award shall be made on the basis of the following qualifications:

(1) The paper must deal with some technical phase of motion picture engineering.

(2) No paper given in connection with the receipt of any other Award of the Society shall be eligible.

(3) In judging of the merits of the paper, three qualities shall be considered, with the weights here indicated: (a) technical merit and importance of material, 45%; (b) originality and breadth of interest, 35%; and (c) excellence of presentation of the material, 20%.

A majority vote of the entire Committee shall be required for the election to the Award. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors at their July meeting for ratification.

These regulations, a list of the names of those who have previously received the Journal Award, the year of each Award, and the titles of the papers shall be published annually in the Journal of the Society. In addition, the list of papers selected for Honorable Mention shall be published in the Journal of the Society during the year current with the Award.

The recipients are listed below by year, with the date of Journal publication given after the title.

1934, P. A. Snell, "An introduction to the experimental study of visual fatigue," May 1933.

1935, L. A. Jones and J. H. Webb, "Reciprocity law failure in photographic exposure," Sept. 1934.

1936, E. W. Kellogg, "A comparison of variable-density and variable-width systems," Sept. 1935.

1937, D. B. Judd, "Color blindness and anomalies of vision," June 1936.

1938, K. S. Gibson, "The analysis and specification of color," Apr. 1937.

1939, H. T. Kalmus, "Technicolor adventures in cinemaland," Dec. 1938.

1940, R. R. McNath, "The surface of the nearest star," Mar. 1939.

1941, J. G. Frayne and Vincent Pagliarulo, "The effects of ultraviolet light on variable-density recording and printing," June 1940.

1942, W. J. Albersheim and Donald MacKenzie, "Analysis of soundfilm drives," July 1941.

1943, R. R. Scoville and W. L. Bell, "Design and use of noise-reduction bias systems," Feb. 1942 (Award made Apr. 1944).

1944, J. I. Crabtree, G. T. Eaton and M. E. Muehler, "Removal of hypo and silver salts from photographic materials as affected by the composition of the processing solutions," July 1943.

1945, C. J. Kunz, H. E. Goldberg and C. E. Ives, "Improvement in illumination efficiency of motion picture printers," May 1944.

1946, R. H. Talbot, "The projection life of film," Aug. 1945.

1947, Albert Rose, "A unified approach to the performance of photographic film, television pickup tubes, and the human eye," Oct. 1946.

1948, J. S. Chandler, D. F. Lyman and L. R. Martin, "Proposals for 16-mm and 8-mm sprocket standards," June 1947.

1949, F. G. Albin, "Sensitometric aspect of television monitor-tube photography," Dec. 1948.

The present Chairman of the Journal Award Committee is C. R. Daily.

PROGRESS MEDAL AWARD

The Progress Medal Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

The Progress Medal may be awarded each year to an individual in recognition of any invention, research or development which, in the opinion of the Committee, shall have resulted in a significant advance in the development of motion picture technology.

Any member of the Society may recommend persons deemed worthy of the Award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration. The recommendation shall be seconded in writing by any two Fellows or Active members of the Society, who shall set forth their knowledge of the accomplishments of the candidate which, in their opinion, justify consideration.

A majority vote of the entire Committee shall be required to constitute an Award of the Progress Medal. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors at their July meeting for ratification.

The recipient of the Progress Medal shall be asked to present a photograph of himself to the Society and, at the discretion of the Committee, may be asked to prepare a paper for publication in the Journal of the Society.

These regulations, a list of the names of those who have previously received the Medal, the year of each Award and a statement of the reason for the Award shall be published annually in the Journal of the Society.

Awards have been made as follows:

1935, E. C. Wente, for his work in sound recording and reproduction, Dec. 1935.

1936, C. E. K. Mees, for his work in photography, Dec. 1936.

1937, E. W. Kellogg, for his work in sound reproduction, Dec. 1937.

1938, H. T. Kalmus, for his work in developing color motion pictures, Dec. 1938.

1939, L. A. Jones, for his scientific researches in photography, Dec. 1939.

1940, Walt Disney, for his contributions to motion picture photography and sound recording of feature and short cartoon films, Dec. 1940.

1941, G. L. Dimmick, for his development activities in motion picture sound recording, Dec. 1941.

No Awards were made in 1942 and 1943.

1944, J. G. Capstaff, for his research and development of films and apparatus used in amateur cinematography, Jan. 1945.

No Awards were made in 1945 and 1946.

1947, J. G. Frayne, for his technical achievements and the documenting of his work in addition to his contributions to the field of education and his inspiration to his fellow engineers, Jan. 1948.

1948, Peter Mole for his outstanding achievements in motion picture studio lighting which set a pattern for lighting techniques and equipment for the American motion picture industry, Jan. 1949.

1949, Harvey Fletcher for his outstanding contributions to the art of recording and reproducing of sound for motion pictures, Oct. 1949.

The present Chairman of the Progress Medal Award Committee is J. G. Frayne.

SAMUEL L. WARNER MEMORIAL AWARD

Each year the President shall appoint a Samuel L. Warner Memorial Award Committee consisting of a chairman and four members. The chairman and committee members must be Active Members or Fellows of the Society. In considering candidates for the Award, the committee shall give preference to inventions or developments occurring in the last five years. Preference should also be given to the invention or development likely to have the widest and most beneficial effect on the quality of the reproduced sound and picture. A description of the method or apparatus must be available for publication in sufficient detail so that it may be followed by anyone skilled in the art. Since the Award is made to an individual, a development in which a group participates should be considered only if one person has contributed the basic idea and also has contributed substantially to the practical working out of the idea. If, in any year, the committee does not consider any recent development to be more than the logical working out of details along well-known lines, no recommendation for the Award shall be made. The recommendation of the committee shall be presented to the Board of Governors at the July meeting.

The purpose of this Award is to encourage the development of new and improved methods or apparatus designed for sound-on-film motion pictures, including any step in the process.

Any person, whether or not a member of the Society of Motion Picture and Television Engineers, is eligible to receive the Award.

The Award shall consist of a gold medal suitably engraved for each recipient. It shall be presented at the Fall Convention of the Society, together with a bronze replica.

These regulations, a list of those who previously have received the Award, and a statement of the reason for the Award shall be published annually in the JOURNAL of the Society. The recipients have been:

1947, J. A. Maurer, for his outstanding contributions to the field of high-quality 16-mm sound recording and reproduction, film processing, development of 16-mm sound test films, and for his inspired leadership in industry standardization (citation published, Jan. 1948).

1948, Nathan Levinson, for his outstanding work in the field of motion picture sound recording, the intercutting of variable-area and variable-density sound tracks, the commercial use of control track for extending volume range, and the use of the first soundproof camera blimps (citation published, Jan. 1949).

1949, R. M. Evans, for his outstanding work in the field of color motion picture films, including research on visual effects in photography and development work on commercial color processes (citation published, Oct. 1949).

The present Chairman of the Samuel L. Warner Memorial Award Committee is W. V. Wolfe.

Board of Governors

The second meeting of the Board of Governors for 1950 was held on Sunday, April 23, in The Drake hotel, Chicago, preceding by one day the opening of the Society's 67th Semiannual Convention. The Board members reviewed the Society's accomplishments and financial picture for the three months just completed. Plans for future committee activities that are supervised by the Officers and Headquarters Staff were also considered at length.

President Sponable introduced F. E. Carlson and M. G. Townsley, recently appointed Governors from the Central Zone, who had been chosen to fill two recently created Governorships that otherwise would have remained vacant until 1951.

Current activities, reported on by Boyce Nemec, Executive Secretary, included the Society's programs for test films, memberships and the Journal.

Sales of 16- and 35-mm test films have remained at a high level, continuing to exceed production so that a number of back orders are still on the books. Production forecasts for the immediate future indicate that deliveries will catch up with orders by the third week in July, and after that it should be possible to begin building an inventory of all films. Twenty-four hour service on all orders for reasonable quantities of any of the films is the prime objective.

The engineering committees have had an abiding interest in generally improving technical performance in the 16-mm field. Recently, steps have been taken in this direction to interest service shops, dealers, and distributors of 16-mm projectors in the test films now available from both the Society and the Research Council. Increased distribution and use of all test films is expected and this program deserves the support of all members.

Users of high-speed photography have recently taken great interest in the work of the Society's High-Speed Photography Committee and in the articles on the subject that appeared in the Journal within the past year. Those who contributed to the Committee's 1949 Survey and their associates, who are not now members of the Society, have been invited to join. A considerable increase in membership from this field, which includes all phases of scientific photography, should result. The Board of Governors endorsed this program enthusiastically, and urged that service engineers whose field is the maintenance of theater and television equipment should also be invited to apply for membership. This is being done and there will no doubt be a further increase of membership in all grades from this quarter.

Now that many of the engineering committees are becoming increasingly active, the amount of correspondence, duplicating, mailing and other overhead required to maintain this level of activity is also increasing. A further increase of administrative expenses is attributed to recent improvements in the Journal, stemming from the gradual revision of typography, together with results from current membership promotion, which necessitates a larger print order each month. Fortunately, however, there are compensating factors here, such as reduced unit cost of the Journal brought about by the increased print order, which takes advantage of quantity production economies. The fiscal picture at the end of the first quarter is an encouraging one but actually is only a beginning, compared with what the Society can do if its members will get squarely behind the present membership and test film programs.

Engineering Vice-President Bowditch reviewed briefly the work of the eighteen different engineering committees that are now active, including the reorganization of television work, reported on page 509 of the April JOURNAL. The outcome of this program, which stresses co-operation with the Institute of Radio Engineers and the Radio Manufacturers Association, should be in the direction of more effective committee work in all three organizations with a minimum of effort. Continuing JOURNAL reports on the Society's work in theater television were requested, at least until conclusive action is taken by the FCC.

Editorial Vice-President Keith reported the receipt of two replies to the article on Research Fellowships that had appeared in the February JOURNAL. The Illuminating Engineering Society currently has a committee considering the granting of such Fellowships, and it was suggested that Mr. Keith look into the matter with representatives from the IES.

The recently proposed Amendments to the Constitution and Bylaws have received official endorsement, and now the committee, under the Society's Secretary, Robert M. Corbin, responsible for that work, has accepted the job of revising the Administrative Practices. These are a set of Board-approved rules governing in a practical way the operations of Society Headquarters and the Society's many committees. Changes will be recommended in order to bring the Administrative Practices into line with the present Constitution and Bylaws.

The next meeting of the Board of Governors, scheduled for July 26, will be held in New York City. In the meantime, the Sustaining Membership Committee, the Membership and Subscription Committee and Society Headquarters will bend every effort toward increasing support which the Society receives.

67th Convention

The Society's 67th Convention opened officially on April 24 with a luncheon at The Drake hotel in Chicago. Members who attended the luncheon were treated to a very enthusiastic statement of intentions in theater television presented by Spyros P. Skouras, President of the Twentieth Century-Fox Film Corp. Mr. Skouras indicated with some emphasis that his company intended to proceed with plans to establish a theater television network in a West Coast area without waiting for formal action by the Federal Communications Commission. Arrangements would be made with the local telephone companies for cable service between theaters and the originating point. Action, he stated, would be taken by early 1951.

Attendance at the Convention was more than satisfactory, with over 200 registrants for the week and an additional 100 daily registrants for each of the five days of the week-long meeting.

Outstanding among those attending were four members of the University of Southern California Student Chapter: Algernon Walker, James L. Wilkinson, William R. Kells and Eric T. Sjolander; and Wilbur T. Blume, a member of the USC Faculty. These five members drove from California to Chicago, stopping at universities along the way to inspect motion picture production and visual education facilities.

There was a total of eleven committee meetings held during the week, running from Sunday, April 23 through Saturday, April 29. Future issues of the JOURNAL will carry progress reports on the work of the majority of these committees.

On Tuesday evening those who attended the convention were guests of WGN-TV Television Station and were escorted through the Tribune Tower Studios at 435 N. Michigan Ave. The studios have been under construction for some time and members who are familiar with studio design and the solution of architectural and acoustics problems were tremendously interested in the choice of materials and their application to this impressive arrangement of combined television and radio facilities. The Society extends its enthusiastic gratitude to Carl Meyers, Director of Engineering, and F. R. McNichol, Engineering Department, WGN TV.

On Wednesday evening, the semiannual Cocktail Hour, Banquet and Dance were held in the Gold Coast Room of The Drake hotel. Bill Kunzmann was as always the Society's genial host and provided a most entertaining evening for all.

On Thursday evening, Wilding Picture Productions was host to Society members who visited the studio at 1345 Argyle St.

The Convention closed late Friday afternoon, April 28, with a few encouraging words from Mr. Kunzmann, who reports that in all respects the Convention was more than a modest success. Papers presented will begin to appear in the JOURNAL beginning in the late summer and will probably continue until about the first of 1951.

Theater Carpeting Manuals Available

The Theater Engineering Committee has for some time contemplated publishing a report on theater carpeting that would be a generally useful guide to theater owners and operators who purchase fairly large quantities of carpeting. It would necessarily have to be quite comprehensive in presenting recommended practices for the selection, maintenance and care of theater carpet based upon actual theater experience. After considerable work in this direction had been undertaken, in the form of a survey, it was decided that certain publications already available adequately covered the major questions on theater and hotel carpeting. The SMPTE has, therefore, made arrangements to secure for interested persons a package of the following two publications:

Handbook for Carpet Layers, The Carpet Institute, Inc.

Carpets and Their Maintenance, prepared for The American Hotel Association by The York Research Corp., in co-operation with The Carpet Institute, Inc., and The National Institute of Rug Cleaners, Inc.

The Committee feels that with this information at hand, and with his personal experience, the average theater man will have available *nearly* all that he needs to know about the subject.

In reviewing these documents, however, various members of the Committee agreed that there are a few additional points unique to theater work that should be added. Pattern selection, for instance, should depend not only on the theater motif, but on the size of the floor areas involved. Large areas usually demand a larger pattern, and the trend has been toward larger patterns with repeats as great as 60 in. Matching background designs are also available without the large pattern, so that the over-all pattern can be used in a foyer and standee area, and the stairways can carry the matched background only. In this way, the large

pattern cannot camouflage or confuse the outlines of the stair treads and risers, and so a higher safety factor can be maintained.

Many theater operators create a much more favorable maintenance schedule by using 54-in. widths rather than 27-in. widths in aisles and standee areas, on stairways and in other heavily traveled areas. This eliminates extra seams which are always a problem as the carpet wears.

Color selection should be studied in every installation. Bright colors that soil "gracefully" and still retain a live look are desirable. Reds and golds especially fall into this class. The manufacturer can give valuable guidance in this instance. Consideration must also be given to color mixing. The problem here is like mixing oil colors in a pot. Green lighting on red carpeting will result in a dead, black effect. Rose or flame-tint lighting, on the other hand, will enhance and soften the effect of red carpeting. A definite trend, however, has been the utilization of low wattage concealed down lighting that *suffuses* the carpeted areas with white light of proper intensity. Wall and carpet areas then reveal their true colors.

Experience has shown that greatly increased carpet life on stairs results when a nosing radius of ½ to ¾ in. is used. Theater architects prefer, for the most part, a ¾-in. radius. The Committee's suggestion for stair lining, in addition to the radii outlined above, is a ¼-in. layer of sponge rubber across the tread and over the nosing. The sponge rubber should end at a point just under the nosing, against the riser. Over the sponge rubber a layer of regular 40-oz lining should be used. The nailing strips should be countersunk, if possible, on the flat tread where the riser begins. The 90-degree pulling force against the carpet nails has proved more satisfactory than that against a wood corner strip.

Aisles should be countersunk approximately ⅝ in. in all new construction. This allows a 54-oz lining plus a good grade of carpeting to fall almost flush with the floor. Here again, nailing strips should be countersunk in the depressed aisle when the concrete is poured. A beveled edge on the strip, with the widest edge buried in the concrete, will prevent pull-out. Plywood strips have been found best because of their greater retention of the carpet nail and because the resins in plywood resist termite infestation.

Determination of quality in purchasing carpet can be confusing to the uninitiated. Experts determine quality by the density of wool per cubic inch. The durability of any carpet varies as the square of density and pile height. Competing samples of carpet should be compared as to pitch, pile height and wire count. These terms are explained in the publications offered. A very important factor in durability is the blending of wool yarns. The larger the proportion of coarse, long staple wool used in a blend of yarn, the greater the durability. Since blends of yarn cannot be specified, the purchaser in this instance can depend only on the reputation of a manufacturer as well as the past performance of his product.

"On location" cleaning is discussed in *Carpets and Their Maintenance*, described above. Careful use of this information will indicate the safest and best cleaning methods available. Particular attention should be paid Part II of this booklet.

The Theater Engineering Committee sincerely hopes that this report of the Theater Carpeting Subcommittee will find acceptance with interested members of the Society and with theater owners and operators everywhere, and that the publications offered herewith will fill a need of long standing. A package of these two publications is available from the Society at $3.00, plus $0.25 for handling and mailing.

American Documentation Institute

Among the organizations with which the Society co-operates, one of truly fundamental importance but little known in our field, is the American Documentation Institute which is now over ten years of age. Its objectives are promotion and development of documentation in scholarly and scientific fields. This rather inclusive statement of aims is reviewed at length in the first issue of *American Documentation*, the Institute's new Quarterly publication, by its editor Dr. Vernon D. Tate, who is better known to the world of science as Director of Libraries at the Massachusetts Institute of Technology. Directors of engineering, research workers and technical librarians who are concerned with scientific reference matters would do well to look into the work of the Institute, paying particular attention to its two publications *American Documentation* and its *Catalog of Auxiliary Publications*, listing documents deposited with the Institute and available on either microfilm or photo copy.

The Winter 1950 (January) issue of *American Documentation* is Vol. 1, No. 1, 58 pp., 8 × 10½ in. in size. Succeeding issues will have a minimum of 48 pp., and are scheduled to contain advertising. Typographically and in content, it is a very creditable job. Its aims, aligned with those of the Institute, are:

"To serve as an impartial clearing house for information about documentation from any source; for the publication of original research in the field; for reporting investigations of new mechanisms, techniques or devices for documentation and their applications; to assist in the development and adoption of basic standards; to provide bibliographic and other control of the literature; to serve as an effective medium for national and international co-operation and exchange in documentation; to stimulate and discuss new ideas and approaches to existing or future problems; for the publication of material originated by the American Documentation Institute.

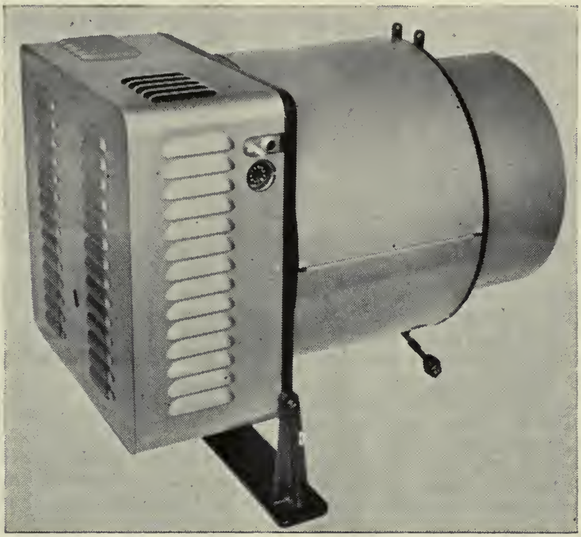
In content *American Documentation* will follow this general outline. It will not duplicate the work of the *Review of Documentation;* it will not follow too closely in the footsteps of its ancestor, the *Juornal of Documentary Reproduction*. Instead, the field of interest has been substantially broadened and particular attention will be devoted to urgent problems in documentation encountered by those engaged in creating, handling, storing and using documents, together with advances in technology. Also covered are microfilm, microprint, microcards, sheet microfilm, photographic technology generally, the new graphic arts including photo-composing machines, Xerography and myriad processes of documentary reproduction, punched cards, digital computers, rapid selectors and facsimile machines. Ultrafax and many other developments all have a place. Approaches to the organization of information, classification systems, semantics and the logic of communication are important. Documentary aspects of graphic portrayal through motion and still pictures, television and the recording and use of sound offer important fields for emphasis. Finally, there are physical and philosophical considerations as yet only dimly perceived that may alter much present thinking; Cybernetics is such a concept.

Annual subscription rate is $5.00 and inquiries concerning subscriptions should be addressed to the American Documentation Institute, 1719 N. Street, N.W., Washington 6, D.C.

Communications regarding manuscripts or other editorial matters should be directed to Dr. Vernon D. Tate, Massachusetts Institute of Technology, Cambridge 39, Mass.

New Products

Further information concerning the material described below can be obtained by writing direct to the manufacturers. As in the case of technical papers, publications of these news items does not constitute endorsement of the manufacturer's statements nor of his products.



Reeves Videon Projection Television has been announced by Century Projector Corp., 729 Seventh Ave., New York 19. Manufactured by the Reeves Soundcraft Corp., the installation consists of the optical barrel assembly, the driver unit, 20-w audio amplifier, remote control unit, screen, screen frame and speaker cabinet, with all connecting cables supplied.

Picture sizes range from 3 × 4 ft, where ambient light is moderate, up to 6 × 8 ft where theater darkness prevails. Remote tuning can be effected up to 100 ft from the screen. Two speakers and cabinets are used with the 6 × 8 ft screen.

The optics of the Videon-Schmitt lens barrel assembly (shown above) are reported engineered for minimum distortion and aberration, with the 14-in. reflector affording minimum loss in light value. The lens barrel can be suspended from the ceiling for front-projection or mounted on a shelf for rear projection.

SMPTE Officers and Committees: The roster of Society Officers is given in this issue, pp. 635–37. The Committee Chairmen and Members were shown in the April Journal, pp. 515–22; changes in this listing will be shown in the September Journal.

Letter to the Editor

In "Color Cinematography in the Mines" by M. Charles Linko, in the February, 1950, JOURNAL, there should have been a credit line showing Mode-Art Pictures, Inc., Pittsburgh, Pa., in whose employ M. Charles Linko was at the time he shot the picture outlined in the article.

J. L. BAKER, President
Mode-Art Pictures, Inc.
1020 Forbes St., Pittsburgh 19

Employment Service

POSITIONS WANTED

With 35-Mm Production Unit: Young veteran desires to learn motion picture production. Will work in any capacity. Single, 23, with 8 yr theater experience, all phases; mgr small house 3 yr; 2 yr A.M.P.S. projectionist supervisor; grad. AAF Photo School and Motion Picture Inst. production course. Have private library of over 200 film books; serious student of films since 15. Currently employed; detailed letter and refs readily supplied; salary no object. John P. Lowe, 265 State St., Northampton, Mass.

Producer-Director-Editor: 10 yr with major film producers. Thorough knowledge and experience script-to-screen production technique: directing, photography, editing, laboratory problems, sound recording, 35- and 16-mm, b & w. Specialist in research and production of educational and documentary films; small budget commercial and TV films. Long experience in newsreels. Desire greater production possibilities, go anywhere. Member SMPTE, top refs. E. J. Mauthner, P. O. Box 231, Cathedral Sta., New York 25.

Mechanical-Electronic Engineer: B.S. degree in Mechanical Engineering; extensive design, mfg. experience, standard and drive-in theater picture and sound equipment; experience as engineering assistant to top management exec. corp. in radio TV. Write A. Kent Boyd, 3308 Liberty St., Austin, Texas.

In Manufacturing: Broad experience in developing, improving and producing of home movie cameras and projectors. Good technical background. Desire position with mfr. Earle F. Orr, 345 Fellsway West, Medford, Mass.

On-the-Job G.I. Bill Training: Ambitious young man to be member of camera crew; grad. U.S. Army Signal Corps Schl.; experienced with Cine Spec., 70DA, Eyemo, Wall and Mitchell cameras; studied editing, art directing and cinematic effects at U.S.C.; married, non-drinker, serious; man for small studio TV work. P.O. Box 524, Alhambra, Calif.

TV and Motion Picture Production Supervisor: 18 yr of unusually complete and varied experience in production of films for theatrical, educational, commercial and TV fields. Heavy technical background in animation, special effects, optical printing, stop-motion, as well as live action. Installed five animation and special effects departments now in operation. Chief cinematographer on U.S. Govt. training films. Experience covers Technicolor, b & w, 35- and 16-mm. Good laboratory background. Would like executive liaison position to supervise production, where creative ability and knowledge of lesser-known techniques could be utilized. Will travel anywhere within U.S. Member of SMPTE for 15 yr. More detailed résumé and references supplied on request. Ernest M. Pittaro, 1930 Grand Concourse, Bronx 57, New York.

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Society of Motion Picture and Television Engineers

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Boyce Nemec, Executive Secretary

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Principles of Color Sensitometry

A Report of the Color Sensitometry Subcommittee

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SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

Foreword

It was the consensus of the members of the Color Committee that a report outlining the principles of color sensitometry would be one of the most urgently needed contributions the Color Committee could make to the membership of this Society and to the industry as a whole.

A Subcommittee was organized in March, 1949, with that objective in mind. They undertook the preparation of a report that would review the functions of color sensitometry, the fundamental concepts involved, their approximate realization in practical use and with available instruments, and the areas in which further research is necessary before definite procedures can be recommended for general adoption.

It was recognized that a rather difficult and insufficiently developed subject had to be presented. It is a matter of great satisfaction to report that invitations to serve on the Subcommittee were accepted promptly and assignments carried out with unusual promptness considering the highly technical and frequently controversial nature of the work. From its beginning, the project has enjoyed excellent support from all quarters in the motion picture industry.

The Subcommittee has stressed the fact that the present understanding of the fundamental principles of color sensitometry is incomplete. Further research is necessary to establish the theoretical foundations of color sensitometry and a great deal of industrial experience is required to evaluate the practical merits of the procedures discussed in this report. However, it is believed that the initial objectives of the Committee have been adequately covered.

It is to be hoped that the technical knowledge and guidance provided by the report will be helpful to the industry and that it also will have the effect of directing industrial practices into channels so that in years to come standardization of the more important aspects of color sensitometry can be undertaken with a greater expectation of unanimity of acceptance than would otherwise be possible in this complex field.

The report of the Subcommittee appears as a uniform, anonymous presentation, reflecting the views of all members. The editing was done by the Chairman, C. F. J. Overhage, who acknowledges the valuable assistance of his associates: A. M. Koerner, R. H. Morris, G. Wernimont in the preparation of Sections III and VIII, and F. C. Williams in the final review of the entire report. Special credit should be given to those members of the Subcommittee who prepared the first complete drafts of the other Sections: L. E. Clark (Section V), A. M. Gundelfinger (Section VI), M. H. Sweet (Section VII), J. P. Weiss (Section II), and F. C. Williams (Sections I and IV). The efforts of the West Coast members of the Subcommittee were effectively co-ordinated by J. G. Frayne.

The Chairman of the Color Committee wishes to express his appreciation to the members of the Subcommittee for their enthusiastic support of the program. Special recognition is due Mr. Overhage who has been the driving force behind the project.

Herman H. Duerr, *Chairman*
SMPTE Color Committee

I. INTRODUCTION

Color photography is an exacting endeavor. When we see a beautiful and apparently accurate color reproduction on a motion picture screen, we see the product of a long train of precision work. It is work with little tolerance of trial and error; errors can run in too many directions and can appear in too many places to be discovered and overtaken by trial. Economical practice of color photography affords little room for operation by guess or even by estimate. It demands operation by measurement. This measurement must result in quantitative knowledge of the character of the materials in use, of the effects of laboratory handling, and of the nature of the photographic images formed—knowledge sufficiently accurate and comprehensive to insure efficient production of best possible results. The science which specifies most of these measurements, and the ways of making them, is photographic sensitometry.

Although the principal concern of photographic sensitometry is the determination of quantitative relationships between photographic exposures and the images they produce, it deals with the entire photographic process from subject to observer. It examines exposures and specifies the kind and amount of radiant energy which the film should or does receive. It tests and helps control the sequences of chemical treatments which form in the exposed material the visible photographic results. It measures the processed images, determining their character or contents in terms most useful for the product's application or most significant in an operation's adjustment or stabilization. Finally, it determines the reactions of observers and relates their quality judgments to physical characteristics of the photographic material. It does these things by employment of techniques and tools which are specialized for the job, and it expresses results in special units and language designed for the purpose.

Color photography has brought into sensitometry new methods, new instruments, and new terms tailored to the new task. They contribute to a new division of the science called *color sensitometry*. Much of color sensitometry is built on basic principles familiar in sensitometry of black-and-white materials. Some principles are new. It is the object of this report to outline these principles and to describe the methods and instruments of color sensitometry in order to give to workers in the field of color motion picture photography a comprehensive view of the present state of the science as it applies to them.

The treatment is not detailed, and in some places rigor has given way for better understanding, but the coverage is intended to be comprehensive.

Color sensitometry is used in the motion picture industry in two broad fields of application: in the *evaluation* of techniques and materials, and in their *control.* As a tool of evaluation it is meant to provide straightforward objective descriptions of color film images and indirectly therefore of the characteristics of a film, or a processing operation, or a printing system. It provides a language in which quality and performance can be discussed. These objective descriptions are especially valuable for comparing photographic films with an ideal, with a practical aim point, with a tolerance limit, or with an alternative product.

Other sensitometric measurements are required in control operations, especially where control is exercised by application of corrective measures to minimize unwanted variations. The manufacturer requires such control to keep his product uniform. The processing laboratory may require it to produce repeatedly the same result from successive processings of identical material.

There is, naturally, wide variety in the procedures used in the diverse applications of sensitometric methods; yet one basic routine is common to nearly all tests: Exposures are imposed on a sample of film, the sample is processed, the resulting images are measured by some densitometric technique, and the data from these measurements are arranged in a form suitable for the required interpretation which follows. The present report takes up these procedures individually, in the order of that routine. For each step, there is discussion of the fundamental concepts involved, and of their embodiment in practical procedures suitable to the motion picture field.

This report is intended to apply primarily to subtractive processes—those in which color variation in the image is achieved by varying the amounts of superimposed dye images, each of which can substract from the incident energy chiefly light of one color. Most of the methods have been developed for use with three-component multilayer subtractive films—those which form cyan, magenta, and yellow dye images in three separate sensitized layers, all on the same transparent support. Many of the basic principles, and some of the specific methods, are also applicable to other color film types. No consideration has been given to color materials with opaque supports such as color-print papers.

II. SENSITOMETRIC EXPOSURES

The basic procedure in color sensitometry begins with the exposure of the test sample. Because of the wide dissimilarity in characteristics and application among various color films, a general discussion of sensitometric exposures must necessarily deal with basic principles rather than specific details. The color products now on the market include taking stocks, print stocks and intermediates. Some color taking films are processed as negatives, others by reversal. Certain print stocks are designed to be printed from separation negatives and some from a colored negative or positive. Each basic type requires a different sensitometric treatment because of its unique characteristics and method of use.

The chief guiding principle is that the sensitometric exposures should duplicate as closely as possible the conditions of actual use. The importance of this has been demonstrated time after time in black-and-white sensitometry, and it is even more pertinent in color. The complexity of color films is much greater than that of black-and-white materials and the tolerances under which a color system operates are closer.

Time vs. Intensity Variation*

In the choice between sensitometers involving a variation of exposure time with constant intensity, and those in which the exposure time is kept constant and the intensity varied over different areas of the films, (time-scale vs. intensity-scale), the principle of simulating conditions of use favors the latter type by an almost overwhelming margin. Because of reciprocity law failure[1] a time-scale more than likely will not give the same result as the intensity-scale involved in actual use. The seriousness of the disagreement will of course depend on the characteristics of the particular film.

In black-and-white photography it has been a fairly widespread practice to use time-scale sensitometric exposures for process control, where it is wished to check reproducibility of development. Sensitometric values are measured on the processed strips and correlated

* In the classical papers of Abney and of Hurter and Driffield, photographic exposure was referred to as the product of "intensity" and time, and this use of the word "intensity" has continued in photography, although it means something else to physicists and illuminating engineers. The Colorimetry Committee of the Optical Society of America has proposed *irradiance* to designate the radiant power incident on unit area of a receiving surface, and *illuminance* for the corresponding luminous power. Pending a general clarification of photometric terms, this report will follow current trade practice in speaking of *intensity*.

with actual pictures. The values associated with optimum picture results are selected as reference values. Once this selection has been made, it is assumed that photographic performance will be maintained at optimum level if the development is always so adjusted that the sensitometric values obtained on processed time-scale test strips remain the same as the reference values. This procedure is fairly reliable as long as the reciprocity characteristics of the film remain constant from batch to batch, and the development conditions (such as developer composition) do not vary too widely. Such assumptions have been found not always valid in black-and-white, and they are much more risky in color. Since the three emulsions of a typical color film are not usually identical in formulation they may well be expected to have reciprocity law characteristics which vary differently as film conditions or development vary. Because the development conditions for the three layers are necessarily different, the influence on reciprocity characteristics of development changes will differ among the three layers. Thus, even for development control, test strips with time-scale exposures are lacking in reliability.

Step Wedges

The ideal device for producing a variable intensity exposure on film would be accurate, reproducible from specification, and would not change the spectral quality of the radiation as it varied the quantity (i.e., would be nonselective). To vary exposure by increasing the distance of the source according to the inverse-square law is technically a perfect solution, but unfortunately results in a sensitometer too enormous and cumbersome to be practical. Optical systems which come very close to meeting the ideal requirements have been described,[2,3] but these have the drawback of being quite complicated and expensive. The step wedge remains the most practical compromise between convenience and economy vs. technical perfection. Both photographic and colloidal graphite wedges which are quite satisfactory for practical sensitometry are commercially available.

While run-of-the-mill step wedges do not qualify for highest accuracy, selected wedges may be found which have quite uniform and accurate steps. The greater the accuracy required the higher the cost of manufacture, so that a top quality wedge is not cheap. For most purposes, such as processing control, highest accuracy is not needed. Again, wedges can be calibrated individually for more accurate data.

The absorption of radiation in its passage through a step wedge

should be the same for all wavelengths. If this is not the case, the step wedge is rather unsatisfactory for color sensitometry. In testing multilayer color film, each emulsion is exposed to only a small portion of the spectrum. A slight yellowish tint which could be ignored in black-and-white sensitometry will cause the wedge densities to be quite different for blue light, say, than for red. In general, photographic wedges are better in this respect than those made of colloidal graphite and thus may be preferred despite the greater accuracy and durability of the latter. The graphite wedges have such significant variation of density with wavelength that for accurate work a separate density calibration is needed for each spectral region. Such calibration is best performed by a system similar to the American standard method for determining contact printing density.[4]

Wedges with 0.15 density increment ($\sqrt{2}$ factor) per step are quite satisfactory for color films. Those with 0.30 density change per step might serve for low contrast negative films, but such steps are entirely too coarse for accurate evaluation of color positive stocks, which ordinarily have quite high contrast. Preferably the wedge should have a density range of from nearly zero to 3.0. A lesser range will sometimes be acceptable because color film does not ordinarily reproduce a very wide subject brightness range.

The geometrical dimensions of each step must be chosen within limits imposed by practical considerations. The cost of test film and the difficulty of providing uniform intensity over a large field prohibit the use of very large areas. On the other hand, a very small area may give misleading results because of adjacency effects[5] and make excessive demands on the sensitivity of densitometers. A step width of 0.4 in. is widely used and appears to be a satisfactory compromise. In a conventional test exposure, the other dimension of each step is at least equal, and may extend across the entire width of the film. Where automatic recording densitometers are to be used, it may be desirable to have a sensitometric strip which varies continuously in density rather than stepwise. This can be achieved by using a wedge with a continuous and uniform density gradient.

Exposure Times and Intensity Levels

To avoid very confusing inaccuracies caused by reciprocity law failure, it is of greatest importance to select an exposure time for a color sensitometer which will be nearly the same as in the camera or printer which actually uses the film. 1/50 sec is probably close to an

average motion picture camera exposure time. In intermittent printers the exposure is apt to be somewhat slower, say $\frac{1}{10}$ to $\frac{1}{20}$ sec, but there is great variation among different machines. Again, the exposure should be applied in a single flash, not an intermittent series of shorter exposures. Obviously an accurate shutter such as a rotating sector disk or drum must be provided, for correct exposures of such duration cannot be achieved by turning the light source on and off.

Once the characteristics of the step wedge are established and the exposure duration selected, the intensity level must be adjusted accordingly, so as to produce exposures at least as great as the maximum given to negatives or prints in use. In designing a sensitometer for color taking films, obtaining sufficient light is not likely to be a serious problem for films used with artificial illumination. If the sample to be exposed is, for example, a 10-in. strip of film fast enough for camera use, then a 500-w lamp will have ample output, and will give even illumination at a distance of about a meter.

Providing enough light to expose a daylight taking film or a color *print* film, on the other hand, may call for unusual sensitometer design. The production of artificial daylight by suitable filtering of radiation from an incandescent source requires rather dense filters. The resulting intensity is therefore low. To match the intensity levels of daylight exposures in cameras with fast lenses requires a 500-w source about 6 in. from the film. Print stocks are inherently slower, and are usually exposed through fairly dense band-pass filters.

One approach toward providing enough light in these cases is to use a short wedge with narrow steps, so the lamp-film distance may be made smaller, still achieving uniform illumination. A second way is to expose only one or two steps at a time, stepping the wedge and film along between exposures of individual steps. Thus the area to be illuminated is very small and the lamp may be extremely close. A variation of this design is to move the wedge and film with uniform velocity past a narrow exposing slit. This eliminates the need of a separate exposure-timing shutter. One such sensitometer has been described by Sweet.[6] Care must be taken to achieve very smooth, uniform motion of the wedge-film carriage, otherwise a striated exposure will result.

Selective Exposures of Individual Layers

The exposure methods most frequently used at present in the testing of color film are (a) to expose the emulsion layer selectively to pro-

duce the individual subtractive colors separately, or (b) to expose them in combination to obtain a gray scale, or both. Actually, each procedure yields some information which the other does not. Making the exposures separately permits simplification of the densitometry of the images, and detection of the presence of any degradation of the primary images caused by migration of color-formers or print-through effects. On the other hand, the image formed in an emulsion layer as a result of a selective exposure which affects only one emulsion layer is somewhat different from the image which would be formed in that emulsion from an exposure which also affects adjacent emulsion layers. This difference is a consequence of inter-layer development effects which may have considerable practical influence on color reproduction. Therefore, complete sensitometric testing of color film should include nonselective gray scale exposures as well as selective exposures of individual layers.

Means of making both types of exposure are discussed under the next heading.

Spectral Quality of Radiation

When making sensitometric tests of a color taking stock, it certainly will be desired to include an exposure to light of the same quality as that which the film receives in the images of white objects under the illumination for which it was designed, e.g., daylight, or 3200 K tungsten. In a reversal film especially, it is important to check that the three emulsion layers are balanced for speed as well as contrast in a gray scale exposure. If the film is balanced for daylight, the sensitometer should be equipped with a combination of light source and conversion filter which will produce simulated daylight. The Davis–Gibson liquid filters[7] give the most nearly accurate conversion, but have some drawbacks for routine use, being prone to leak after a time. The Corning Series 5900 are probably the next best and are permanent and convenient to use. Unfortunately, such combinations, while giving a pretty good visual match, are not a perfect spectral match for true daylight; therefore, the relative speeds of the three layers as determined from the artificial daylight exposure will not be exactly those which would be determined from exposure to natural daylight. The search for better conversion filters continues: Bingham[32] has discussed the design of a filter consisting of two colored glasses between which is cemented a gelatin layer containing four dyes. However, it must be borne in mind that natural daylight itself varies a great

deal in its spectral composition, and that at best a source-filter combination can only simulate a single condition (for example, one of the five phases of daylight described by Taylor and Kerr[33]). Finally, it must be pointed out that the filter problems become less severe as the color temperature of the primary light source is increased. Sensitometer lamps used with conversion filters should, therefore, be operated at the highest color temperature consistent with acceptable stability and lamp life.

Filters with fairly narrow spectral transmission bands are required to expose the individual emulsion layers selectively. The choice of peak wavelength and band width will be dictated by the position of film sensitivity peaks and the degree of overlap in the sensitivity of the three layers. In some color films the sensitivities may overlap so much as to make it impossible to confine a full-scale sensitometer exposure to a single layer with any filter. The film manufacturers will be able to recommend the most appropriate filters for their products. In the case of color print films these may be the same filters as recommended for printing from separation negatives.

Exposures for Sound Track Control

Sensitometric exposures for sound track control of a print film will be quite similar to those used for picture control. Some differences in exposure times and printing filters may be encountered, and the sensitometry must be modified accordingly to simulate use more closely if these differences are large enough. In particular, the filter used for printing the sound track may not confine the image to a single emulsion layer, in which case it will be especially important to follow actual practice.

In some color films the processing of the sound track area includes special treatments (e.g., the conversion of positive silver halide to silver sulfide) that are not applied to the picture area. When this is the case, sensitometric exposures must be similarly treated. This may require placing the test exposure on the film in the sound track location so that it will go through the track-treating device.

When color taking stocks are used for sound recording in single-system cameras, the track exposure time becomes substantially different from the picture exposure. For rigorously accurate sensitometry, the exposure time for the sound track test should follow suit, which calls for quite radical sensitometer design, as has been described by White.[8]

III. THE PROCESSING OF SENSITOMETRIC TESTS

The image which results from the processing of a controlled sensitometric exposure is determined by two factors: (a) the characteristics of the particular piece of film on which the exposure was made, and (b) the characteristics of the process through which the film passed. Normally, both sets of characteristics change with time. If one of these factors can be held constant, sensitometric images can be used as controls for the other factor. This has been attempted in two ways:

(1) To study variations between different samples or different coatings of the same type of film, sensitometric exposures are handled on a "sensitometric process" that is considered constant and free of the day-to-day changes and gradual drifts of the normal production process.

(2) To study variations between different performances of the same process (different machines, different processing stations, or different days on the same machine), sensitometric exposures are made on a reference emulsion ("check" or "type" emulsion) that is considered uniform throughout, and free of the gradual variations that normally occur with the passage of time.

Sensitometric Processes

If one is interested in determining the characteristics of a film sample, as is the case when sensitometric exposures are used for purposes of manufacturing control, or of evaluating deliberate changes in the product, or of determining the effect on the film of pre- and post-exposure storage conditions, then the characteristics of the process through which the film is passed must be known to a degree of accuracy which is commensurate with the accuracy to which it is desired to determine the film characteristics. This calls for rigorous control of the variables which occur in the chemical composition of the solutions, solution temperatures, agitation, etc.

It is usually felt that these factors are not sufficiently well controlled in processes used for production purposes to guarantee an adequate evaluation of the film characteristics. For this reason, so-called sensitometric processes are often set up for the purpose of determining film characteristics. These sensitometric processes differ from production processes in several ways.

In the first place, sensitometric processing machines are smaller and capable of handling only a limited amount of work. The small size of the machine permits the use of small volumes of processing solutions. Because of their small volumes, these solutions can economically be discarded after each processing so that the danger of lack of control through solution deterioration is minimized. Furthermore, because of the small volumes involved, individual batches of the dry chemicals used in making tank solutions will last a long time, whereas in the production processes frequent changes from batch to batch are required. Thus the danger of lack of control arising because of variations between batches of chemicals is also minimized. For weighing the small amounts of chemicals involved in the sensitometric process, more precise equipment can be employed. In mixing, greater care can be taken to avoid excessive stirring in of air. The timing and temperatures of mixing can be rigorously duplicated. In general, the whole operation of setting up chemical solutions can be conducted on a laboratory rather than on a production basis, and higher precision can be expected in the extent to which processing solutions meet specifications.

Furthermore, in the sensitometric machine an effort is made to specify and control the degree of agitation more accurately. In one type of machine,[9] agitation is produced by a set of vanes, which move up and down or across the tank. These vanes can be set and maintained at specified angles to the plane of the film, and their speed of movement and number of trips back and forth can be accurately controlled. The temperature of the processing solutions can also be more precisely held at a predetermined figure.

Thus it should be possible in a sensitometric process to control much more closely each of the physical and chemical characteristics of the process.

Chemical Control

An important adjunct to the maintenance of a sensitometric process is the use of chemical analyses. These are of primary importance in checking the uniformity of the dry chemicals and in making up the processing solutions. It is often assumed that sufficient uniformity from batch to batch is assured by the manufacturer's tests prior to shipment, but it must be remembered that the manufacturer's checks may not be designed to test the chemical under the particular conditions of use to which it is put in the customer's process. The most

effective safeguard, therefore, is to set aside special batches of chemicals for use in the sensitometric process, and to conduct special comparison tests when it becomes necessary to change to a new batch.

Chemical analyses are also available to check the concentration of each of the important constituents in processing solutions. While this is one of the major control methods in production processes,[34] its use in sensitometric processes is limited by the fact that chemicals can be weighed out and mixed with greater accuracy and precision than that with which chemical analyses can be made. The method therefore provides insurance only against gross errors in mixing. The performance of the analyses is also an expensive operation involving the use of specialized personnel and equipment. For these reasons, sensitometric processing machine solutions are rarely analyzed.

Comparison with Production Processes

In setting up a sensitometric process for the purpose of checking film characteristics, it is a fairly obvious requirement that the sensitometric process must closely match the production process through which the film in question is normally used. This match should exist not only for the over-all process but also for each step in the process. Hence sensitometric processes are usually set up progressively, by stages, each of which must yield a photographic result which matches that from the corresponding stage in the production process.

The procedure of establishing the sensitometric process usually starts from the assumption that chemically the processing solutions used must be identical with the seasoned solutions in the production machine. Any adjustments that are necessary to give the same photographic results will be made in the physical factors and not in the chemical phases. It is usually considered desirable that the two machines should also be matched with respect to the temperatures of the processing solutions, and with respect to the time the film is in each step of the processing sequence and each passage between successive solutions. The principal controls available to create a match in the photographic results are, therefore, the mechanical adjustments which vary the agitation of the solutions in the sensitometric machine. When these controls are insufficient, minor changes in solution composition are resorted to. It is often true that even under the best of conditions an exact match cannot be obtained between the two machines. Under these circumstances the sensitometric machine will

still be found to be a useful tool, but the discrepancy from production results must always be borne in mind.

Check Emulsions

The problem considered thus far has been the use of sensitometric exposures for the purpose of determining film characteristics. If one is interested in the determination of processing characteristics, for example in studying the day-to-day behavior of a production machine, sensitometric exposures will again be used, but it is now essential that film variations are not superimposed on the process variations which are to be detected. This requires the use of a check emulsion.

The check emulsion is simply a uniform batch of film of a type similar to that which is normally handled in the process under discussion. Such a batch is selected after making repeated processings of sensitometrically exposed samples and determining, from the average of these results, the photographic characteristics to be expected on this film. The extent to which the results on any subsequent processing of a sample of this film agree with the above average is taken as a measure of the degree to which the process is in control.

The use of a check emulsion for the determination of processing variations rests on the assumption that its pre-processing characteristics do not change in time and are uniform throughout the coating. This is not completely valid for any actual film, and several precautions must be taken to keep the departures from the ideal state sufficiently small to prevent serious errors.

(1) Photographic films are not stable in their exposed or unexposed states. Although film stability is increased by storage at low temperatures, no practical conditions are known at which complete stability can be assured. Thus it cannot be assumed that the check emulsion will remain constant indefinitely.

(2) The effect of the exposure on the film does not remain constant for long periods of time prior to processing. Latent image growth or decay occurs. Thus the time consumed between exposure and processing, as well as storage conditions during this interval, if it is appreciable, must be carefully controlled.

(3) No large batch of film is completely homogeneous; variations occur within the area of a coating. For precise work, it must be recognized that such variations may exist in the check emulsion. They can be evaluated and discounted, however, by using for each

test a number of properly randomized samples of the check emulsion coating.

Aside from errors caused by variations in the check emulsion, there is a fundamental hazard in this method of process control. The process may not be actually in control even when sensitometric tests on check emulsion samples yield normal results. Such a situation may arise when one off-standard condition in the process (say in agitation) has been counteracted, so far as its effect on the check emulsion is concerned, by a second off-standard condition (say in temperature). Although the effects of these two off-standard conditions counteract each other in the check emulsion, it cannot be assumed that they will always similarly counteract each other in other emulsions which are to be handled in the same process. The danger of errors of this type can be minimized by supplementing the sensitometric tests with other control methods, such as determinations of temperatures, flow rates, and chemical concentrations.

Process Control

The preceding sections have outlined the principles which govern the processing of color sensitometric exposures. The ultimate goal, as in all test techniques, is to hold one group of variables constant while studying the changes in another. It will be clear from what has been said that only an approximation to this ideal state can be achieved. Sensitometric processes are not perfectly repeatable, nor are check emulsions perfectly stable. Individual sensitometric results will always be somewhat influenced by secondary variations in factors that should, in principle, be constant. The combination of many individual results by statistical methods and their interpretation by previous experience constitute the precarious art of process control, for which color sensitometry is merely one of the basic tools.

Table I. Descriptions of Color Density Types

Color densities can be divided according to geometrical properties of the densitometer:

Specular Densities. The incident light is collimated; the receiver has a very small aperture accepting only undeviated light.

Diffuse Densities. (a) The incident light is nearly collimated; the receiver accepts all transmitted light, or (b) The incident light is diffuse; the receiver has a small aperture. *Page 670.*

Color densities can be divided according to purpose:

Integral Densities. The effects of image absorptions are expressed in terms of decrease of response of some kind of receiver in an optical system. *Page 669.*

Analytical Densities. Composition of the image is stated as amounts of component absorbers (e.g., cyan, magenta, and yellow dye deposits). *Page 678.*

Integral densities can be divided according to the kind of response that is controlled by the image, or the kind of receiver in which that response is generated. For measuring each type of density, the densitometer must provide the corresponding spectral weighting of the image transmittances:

Printing Densities. In normal film use (printing), the receiver is a print material; the response is latent image formation. In a densitometer, the receiver is usually a photocell in combination with suitable filters. *Page 671.*

Colorimetric Densities. In normal film use (viewing), the receiver is the mechanism of vision; the responses are the component colorimetric responses of a standard observer (e.g., the 1931 ICI observer). In a densitometer, the receiver is usually a photocell in combination with suitable filters. *Page 674.*

Luminous Densities. In normal film use (viewing), the receiver is the mechanism of vision; the response is the luminosity response of a standard observer (e.g., the 1931 ICI observer). In a densitometer, the receiver is usually a photocell in combination with suitable filters, or the visual mechanism itself. *Page 675.*

Arbitrary Three-Filter Densities. These densities do not correspond to a specific film use. In a densitometer, the receiver may be the visual mechanism or a photocell; the response is whatever the receiver gives in the employed optical system, usually using arbitrary red, green and blue filters. *Page 675.*

Spectral Densities. These densities are important for fundamental description rather than the direct representation of a specific film use. In a densitometer, the receiver may be any detector of radiant energy of a narrow wavelength interval—ideally a single wavelength. *Page 677.*

Analytical densities can be divided according to the kind of component which is assumed to make up the image, and the scale on which the amount of that component is expressed:

Spectral Analytical Densities. The assumed components are usually the dye deposits of the color process; the amount of dye is expressed as its spectral density at some one wavelength. *Page 678.*

Equivalent Neutral Densities. The assumed components are usually the dye deposits of the color process; the amount of dye is expressed as the luminous density of the gray image which could be formed by adding to the single-dye deposit under consideration sufficient quantities of the other dyes of the color process. *Page 680.*

Equivalent Neutral Printing Densities. The assumed components are usually the dye deposits of the color process; the amount of dye is expressed as the printing density of the image which could be formed by adding to the single-dye deposit under consideration sufficient quantities of the other dyes of the color process to form an image with red, green and blue printing densities all equal. *Page 682.*

IV. QUANTITATIVE EVALUATION OF THE IMAGE*

Sensitometric tests emerge from the processing operation in the form of processed film samples. These samples usually contain test scales, which are sets of small, uniformly colored areas which have received precisely controlled exposures. Each of these areas may be regarded as a color filter, with absorption characteristics determined by the exposure and processing it received and the characteristics of the film which the test sample represents. The sensitometrist desires certain information about the exposure, the processing, or the film characteristics. He obtains it by measuring the light absorption characteristics of the test areas.

The kind of measurement used depends on the kind of information wanted. Measurements called *integral densitometry*[16] are used to determine the effects which the absorptions of the image will have on some action of the light beam which it attenuates, such as on the printing of a positive material or on the stimulation of an eye. Measurements called *analytical densitometry*[14] are used to determine the composition of the image in terms of amounts of its component absorbers, such as the amounts of yellow, magenta, and cyan dye which together may form an image.

Integral Color Densitometry

Any color transparency produced by a motion picture laboratory will be used, if at all, in some kind of optical system. Integral color densitometry, therefore, must determine the effect of the transparency, when inserted in the optical system, on whatever response the system is intended to generate. The systems of principal interest in the motion picture field are photographic printers (contact and projection) and projectors. They are examples of the larger classes, printing and viewing systems. The response generated in a printing system is a photographic response—the formation of latent image in a print material. Densities which describe the action of transparencies in decreasing this response are *printing densities*.[10] The response generated in a viewing system is a visual response—the stimulation of color receptors in the visual mechanism. Densities which describe the action of transparencies in decreasing this response are *colorimetric densities*.[14]

* *Note:* A summary of the terms introduced in this section to describe different types of density is given in Table I, on the page opposite.

The effect of a transparency (by which is meant here and henceforth a uniformly colored area of processed film) on either a photographic response or a visual response can be determined quantitatively by actual use of the photographic material or the visual mechanism, but the procedures are difficult and slow. For routine operations an instrument—a *densitometer*—is used in which the response of a photoelectric cell or other receiver replaces the photographic or visual response. In either case the absorptions of the transparency reduce the power of the incident light to produce the response. The function of the densitometer is the exact determination of the reduction of the response caused by the film in a given practical application.

Effects of Scattering

Transparencies scatter light as well as absorb it. A densitometer which correctly evaluates the transparency's action must correctly evaluate the effects of this scattering. This would seem to require for each projector system or printer system a densitometer with an optical system essentially duplicating that of the projector or printer. Actually, this is not required. Color transparencies which scatter appreciably usually confine most of the scattered radiation to a cone of very small apex angle, centered on the undeviated ray. The apertures of practical optical systems are large enough to accept the entire cone, except for marginal rays. The aperture of the densitometer must be at least large enough also to accept the cone of principal scattering. If the aperture is larger than this cone, only small errors will be incurred. If *all* the light transmitted by the transparency—scattered and unscattered—is accepted by the densitometer optical system, its density evaluation will still be satisfactory for most purposes. Such instruments are said to measure *diffuse density*. They are generally accepted as best for standardization to insure agreement among several instruments.

Spectrum Weighting

Correct evaluation of the transparency's absorption requires careful treatment. Color transparencies are usually highly selective in their transmission of different portions of the spectrum. The responses which they affect are normally selective with respect to different portions of the spectrum. It is, of course, the interaction of these selectivities that makes color vision and color reproduction possible. It is

obvious that a transparency which looks green should have a lower density to green light than to red or blue light. But its exact density to green light depends on the exact quality of green light used. If a densitometer is to evaluate the spectral transmittances of a transparency in exactly the same manner as they would be evaluated by a print material, the spectral response of the densitometer must meet certain rather rigorous requirements.

Printing Densities

Three factors determine, for any printing system, the power of light of any wavelength, λ, to contribute to the photographic response: (a) the rate, $J(\lambda)$, at which energy of that wavelength is emitted by the printer source; (b) the efficiency, $e(\lambda)$, with which the printer transfers that energy to the print material; and (c) the sensitivity, $S(\lambda)$, of the print material at that wavelength. The photographic effect of the radiant energy of this wavelength, λ, falling on the print material will then be proportional to the product, $J(\lambda) \cdot e(\lambda) \cdot S(\lambda)$. The total photographic effect of all the energy falling on the print material will be the sum of the intensities of the individual wavelengths. Written as an integral, the sum is

$$\int_0^\infty J(\lambda) \cdot e(\lambda) \cdot S(\lambda) \cdot d\lambda.$$

Suppose a transparency is inserted into this optical system, and that at each wavelength, λ, it has a transmittance, $T(\lambda)$. The effect of radiant energy at each wavelength, λ, is now smaller by the factor, $T(\lambda)$. The total photographic effect of all the energy falling on the print material is

$$\int_0^\infty J(\lambda) \cdot e(\lambda) \cdot S(\lambda) \cdot T(\lambda) \cdot d\lambda.$$

The ratio of the second sum to the first is the printing transmittance of the transparency. The common logarithm of the reciprocal of this ratio is the printing density of the transparency, or

$$D_p = \log_{10} \frac{\int_0^\infty J(\lambda) \cdot e(\lambda) \cdot S(\lambda) \cdot d\lambda}{\int_0^\infty J(\lambda) \cdot e(\lambda) \cdot S(\lambda) \cdot T(\lambda) \cdot d\lambda}.$$

A simple densitometer for measuring printing densities may have a source emitting energy at the rate, $J'(\lambda)$, which is transferred with efficiency, $e'(\lambda)$, to a photocell with spectral sensitivity, $S'(\lambda)$. The

density of the transparency as determined by this densitometer will be

$$D'_p = \log_{10} \frac{\int_0^\infty J'(\lambda)\cdot e'(\lambda)\cdot S'(\lambda)\cdot d\lambda}{\int_0^\infty J'(\lambda)\cdot e'(\lambda)\cdot S'(\lambda)\cdot T(\lambda)\cdot d\lambda}.$$

The only condition which will make $D'_p = D_p$ for all possible distributions, $T(\lambda)$, is identical spectral distributions of the products $J(\lambda)\cdot e(\lambda)\cdot S(\lambda)$ and $J'(\lambda)\cdot e'(\lambda)\cdot S'(\lambda)$. Means of accomplishing this condition in practical densitometers are discussed in Section V of this report.

Printing densities are familiar to workers in black-and-white sensitometry.[10] But in black-and-white photography an area of the image has only one printing density in a given photographic system. A color transparency usually has three; either it is printed on three differently (red, green and blue) sensitized materials, or through three dissimilar (red, green and blue) filters. Print-density color densitometers are, therefore, set up to permit rapid shifts among three spectrum-weighting functions, each designed for one of the three $S(\lambda)$ or $e(\lambda)$ distributions. The resulting densities are called *red-printing densities*, *green-printing densities* and *blue-printing densities*. If the three sets of density values of a test scale are plotted against the logarithm of exposure, three characteristic curves result as in Fig. 1. These three curves accurately and adequately describe the printing characteristics of the test scale.

Printing Densities of Other Materials

A densitometer which provides spectrum-weighting functions as described above always reads densities in terms of printing on a *specific* print material, but it will read densities of *any* transparency material. Its use is not confined to the measurement of densities of the negative or positive material which is normally used with that print material. It will measure equally well the printing densities of any other absorber—any negative or positive transparency image, or a silver deposit, or a gelatin filter (disregarding scatter effects). This feature is frequently of considerable value. For example, a printing operation may require reduction of red-printing exposure by a factor of 4, and this is to be done by inserting a red-absorbing filter into the printer optical system. The required filter will have a red-printing density of log 4 = 0.60, as read by the print-density densitometer set

up for the material with which the filter is to be used. Red-absorbing filters invariably absorb green and blue light also; if the effects of these absorptions on the green-printing and blue-printing exposures need be known, printing density measurements also will give this information.

A word of warning is in order, however, in connection with these measurements. It is difficult in practice to adjust the spectrum-weighting functions of a densitometer precisely to the required forms. Approximations are usually necessary. These approximations are chosen to provide minimum errors in the densities of the materials

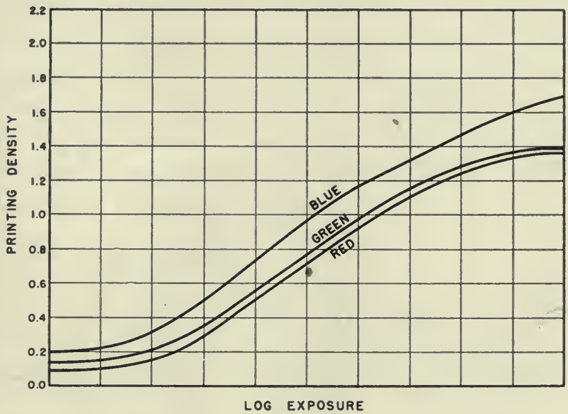

Fig. 1. Printing density plot of the characteristic curves of a typical color negative material. Red-, green-, and blue-printing densities are plotted against the logarithm of exposure. The resulting curves describe the properties of the negative with respect to a specific print material.

usually measured. They may result in appreciable errors in measurement of densities of materials which have spectral transmittance curves different from those of the materials usually measured.

Colorimetric and Luminous Densities

Printing densities are only one kind of integral density. Many color transparencies are not used as intermediate steps of a photographic process, but are intended for direct viewing. Included in this class are direct-reversal amateur motion picture films and release print color films. For these films, measurements of integral image characteristics should determine the effects of the image absorptions

on the visual characteristics of the transmitted light. These are colorimetric measurements.

A unit called *colorimetric density* can be defined and specified in a manner similar to the defintion and specification of printing density. In terms of the trichromatic concept of color vision, the psychophysical color characteristics of light depend on the amounts of three dissimilar responses which it evokes in the visual mechanism. In a colorimetric system each of these responses is assigned a spectral distribution of sensitivity just as each of the three layers of a color print material has a spectral distribution of sensitivity. The spectral dis-

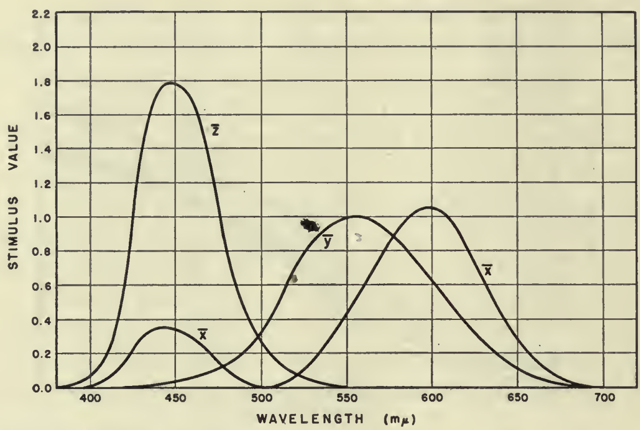

Fig. 2. Spectral distributions of the tristimulus functions of the ICI standard observer. These curves may be considered as the color responses of the visual mechanism, analogous to the red, green and blue sensitivities of a color print material.

tributions of the color responses are called stimulus functions. One response is primarily red-sensitive, one green-sensitive and one blue-sensitive, again like most color print materials. Figure 2 shows the spectral distributions of these functions as used in the system of the International Commission on Illumination. Apparently, then, a densitometer can be specified which will determine the effects of a transparency's absorptions on the amounts of these color responses, and therefore, on the color of the image. It is only necessary to replace, in the equations used for the print-density densitometer, the print-sensitivity distributions, $S(\lambda)$, by the color stimulus functions, $\bar{x}$, $\bar{y}$ and $\bar{z}$.[11] The densitometer then becomes a direct-reading color-

imeter except that it reads, rather than color-stimulus values, a density unit which is the negative logarithm of the ratio of a color-stimulus value, as reduced by the transparency's absorptions, to the stimulus value before that reduction. This unit has been called a *colorimetric density.*

In the current practice of color sensitometry, colorimetric densities are seldom determined. There are several reasons for this. One is that another type of densitometry to be discussed later (analytical densitometry measuring equivalent neutral densities) gives descriptions of images satisfactory for most purposes to which colorimetric densities would be applied. Another is that colorimetric characteristics of the image can be determined qualitatively by direct observation of the image, and such determination is often sufficient.

It is frequently desirable to compare two images with respect to their brightness, even when their colors are different. This is done by use of *luminous* density, which is the negative logarithm of the luminous (brightness) transmittance of the image, and is identical with the $\bar{y}$ density in the colorimetric system.

Arbitrary Three-Filter Densities

There are in widespread use in color densitometry many instruments in which densities are determined by using light filtered through red, green, and blue filters chosen only with the object of getting some kind of red, green and blue light. These densitometers do not read printing densities or colorimetric densities; they read an arbitrary kind of integral color density in which the color response functions employed are those which the particular filters, photocells, etc., happen to give.

These densitometers, and their readings, are quite satisfactory for some purposes. They will determine whether two images have identical colors, provided both images are formed of the same dyes. For if two images, formed of the same dyes, are matched in color, they must have identical spectral absorption curves; they will therefore have identical effects on the stimulus values of any color densitometer system. They will also have identical printing densities for any material. These densitometers are therefore satisfactory for comparisons of identical or nearly identical images. Some control applications require only this type of comparison. Consistency of color processing over a period of time is usually tested by examining the images formed at various times in identically exposed samples of the

same film. For determining whether the processing results are identical amost any density readings with red, green and blue light will do. They will determine in a general way the direction of any processing difference.

But the limitations of such densitometry should be recognized and kept in mind. The density readings cannot be safely used as direct indications of printing density or of image color; large errors may result, particularly in judging samples of high density. It is not safe to compare by means of these density readings a light image with a dense image. The two images may have identical sets of differences

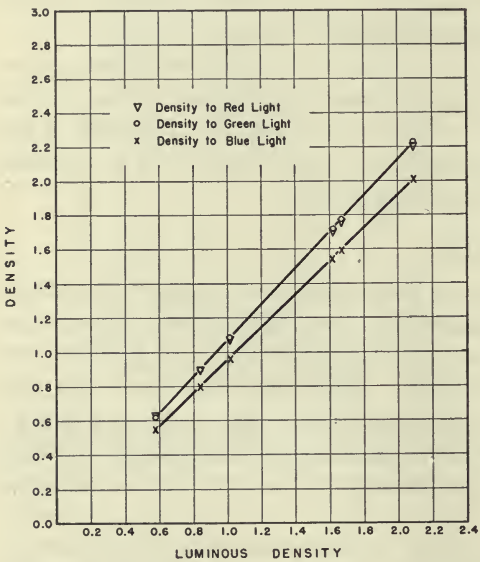

Fig. 3. Three-filter densities of a set of gray images in a direct-reversal color film. Red, green and blue densities for any given step have different values, and the differences vary with the absolute density level.

among their red-light, green-light and blue-light densities, yet be widely dissimilar in chromaticity (color without respect to brightness). Or conversely, they may be identical in chromaticity yet have widely dissimilar sets of density differences. Figure 3 illustrates this latter case; it shows densities of a set of gray images in a direct-reversal color film, determined by using a visual densitometer equipped with Wratten filters Nos. 25 (red), 58 (green) and 47 (blue). The densities to red and green light are very nearly the same, but the differences between these densities and the density to blue light varies from 0.08 to 0.22.

Spectral Densities

Integral densitometry includes the measurement of spectral density, an integral density of increasing importance. Spectral densities are those measured by use of light of a single wavelength.

Spectrophotometers measure spectral densities, or spectral transmittances from which spectral densities can be computed. A curve of spectral transmittance vs. wavelength is a complete description of the absorption properties of an image. It is basic information. From it can be computed the density value of the image in any kind of integral density unit for which the weighting factors are known. The accuracy of results thus obtained is usually better than is obtained from instruments in which automatic weighting has been incorporated. Thus, in colorimetry the effects of an absorber in reducing stimulus values of an illuminant are most accurately determined by using the spectral transmittance curve with standard weighting functions.[11] The effects of an absorber in reducing the actinic power of a beam of light can be similarly computed. But there are two limitations on the usefulness of this method: (a) Too much time and labor are required in determining the spectral transmittance curve and in the subsequent computations, and (b) too few spectrophotometers can determine the spectral densities of the densest images required in color sensitometry.

Densitometers for determining spectral densities are discussed in Section V. The usefulness of spectral densities is the result of two important features: (a) Means of measuring spectral density can be rigidly specified, and (b) spectral densities are additive. Because the methods of measurement can be rigidly specified, spectral density is useful for writing specifications of image characteristics. If two parties agree on what certain spectral densities of an image should be, they can independently test for conformance with specification with good prospect of agreement in result. Other types of density are more arbitrary in nature; they depend on specification of such things as spectral sensitivity of a print material, the spectral absorption characteristics of a set of dyes, or the color-vision characteristics of the densitometer operator. The fact that spectral densities are additive means that the densities of two separate absorbers can be measured with assurance that the sum of those two densities will give (excepting surface and scatter effects) the density of the superimposed combination of those two absorbers. This feature greatly simplifies

calculations of characteristics of transparency combinations. Because of their additivity, spectral densities are essential data for one type of analytical densitometry.

Analytical Color Densitometry

Integral densities always describe some action of the color image as a whole. They do not directly yield information about the image composition in terms of the individual amounts of the dyes. Some knowledge of this content is often useful. When the processed images are not right for a given purpose, it usually is necessary to apply corrective measures that affect the concentration of the image substances. It is useful to know which components of the image are incorrect, and in what direction and degree they depart from their required amounts. Such information is obtained by analytical densitometry.

A subtractive color process image usually is thought of as made up of a cyan dye image, a magenta dye image and a yellow dye image. With certain reservations, this concept is essentially correct. The cyan dye primarily absorbs red light, the magenta dye primarily absorbs green light, and the yellow dye primarily absorbs blue light. But to a smaller extent the cyan dye also absorbs green and blue light, the magenta dye absorbs blue and red light, and the yellow dye absorbs green and red light. Integral density measurements show the total effects of all these absorptions. Analytical density measurements determine the individual amounts of each of the three dye deposits. Instrumental means of making these measurements are discussed in later sections of this report. The amounts of dye deposits or other image components thus determined can be expressed in any of several useful density units.

Spectral Analytical Densities

Perhaps the simplest of these units is a spectral density of the dye deposit; that is, the amount of dye is expressed as its spectral density at some one wavelength. Figure 4 shows as curve N the spectrophotometric curve of a gray image formed by a typical subtractive color process. Curves Y, M and C show spectrophotometric curves of the yellow, magenta and cyan component images which together form the gray. At λ_1 (440 mμ) the integral spectral density of the gray image is 1.82. That is the sum of the density contributions, at that wavelength, of all three dyes. The contribution of the yellow dye is only about 1.33. This figure, $Y = 1.33$, is an analytical den-

sity. It is the density of the yellow component of the gray image, expressed in terms of its absorption at λ_1. Similarly, the density of the magenta component of this image is 1.38 if it is expressed in terms of absorption at λ_2 (535 mμ), and the density of the cyan component is 1.84 if it is expressed in terms of absorption at λ_3 (670 mμ). Means of obtaining these analytical density values from the integral density measurements are discussed in Section VI of this report.

The density figures obtained in this example ($Y = 1.33$, $M = 1.38$, $C = 1.84$) are not particularly descriptive of the appearance to be expected of the integral image; it is not evident from them that they are the components of a gray. For some purposes this need not be

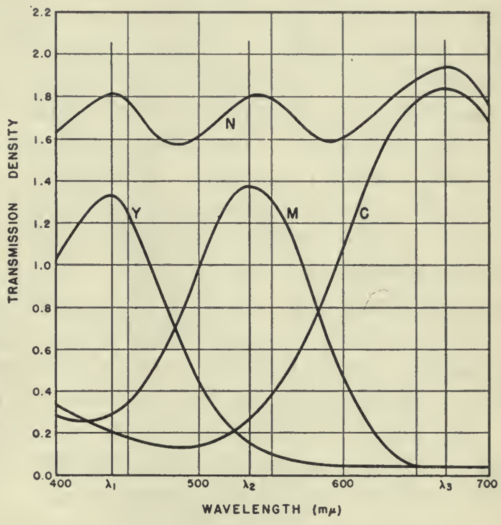

Fig. 4. Spectral densities of a gray image (N) (visual density 1.72) obtained in a subtractive color process, and of its yellow (Y), magenta (M) and cyan (C) component images.

evident. If a specification of the desired contents of the image has been made in these terms of spectral analytical density, the density figures permit comparison, component for component, of the image obtained with the one desired. If the desired components were $Y = 1.33$, $M = 1.53$ and $C = 1.84$, the analysis reveals that only the magenta component is in error, and that it is 10% low. This is definite and sometimes adequate information. It is for some purposes a better comparison of specified and realized images than would be obtained by use of integral spectral densities. In terms of integral spectral densities, the specification of the image with 10% more magenta would have called for densities of 1.85, 1.95 and 1.94, at λ_1,

λ_2 and λ_3. The measured spectral integral densities, 1.82, 1.80 and 1.94, show that the obtained density to blue light is low by 1.6%, the density to green light is low by 7.7%, and the red absorption is correct. It is not evident that the deviations from specified densities are caused by having 10% too little magenta.

Equivalent Neutral Densities

The usefulness of the analytical density values can be greatly increased by selecting density units which give a better description of the integral image. The unit in most widespread use is variously called "gray equivalent density" after Heymer and Sundhoff,[12] who first published its description, or "equivalent density" after Evans,[13] who independently developed the concept in this country, or "equivalent neutral density." Evans defined the equivalent density of a component of a subtractive color process as the luminous density it would have if it were converted to a gray by superimposing the just required amounts of the other components of the process. If the amounts of the components of an image are expressed in this unit, each of the density figures tells how dense a gray that component can form. In the example of analysis already given, the visual density of the gray represented by curve N is 1.72; that is, to the eye, the somewhat selective absorber, N, with spectral densities ranging from 1.58 to 1.94 looks like a nonselective gray of density 1.72. In terms of equivalent neutral density, each of the component absorbers, Y, M and C, of this image also have a density of 1.72.

The most valuable feature of the equivalent neutral density unit is this: Three components which together will make a gray must all have the same equivalent neutral density. Comparison of the equivalent neutral densities of the components of an image will therefore tell directly whether that image is gray (assuming illumination with a specific light quality). If the three component densities are not identical, the comparison will show the direction and amount by which the image deviates from gray, though not in standard colorimetric terms. To a close approximation, specification in terms of equivalent neutral density permits comparison of the chromaticities of light and dark images, since the same set of differences in densities means nearly identical chromaticities.

The fact that equivalent neutral densities show directly the visual densities of grays makes this unit of considerable advantage in work

requiring computation of brightness ratios in the images as functions of brightness ratios in the original scene, that is, in "tone reproduction" problems. These problems are met in motion picture practice in the adjustment of duplication processes and in special effects work.

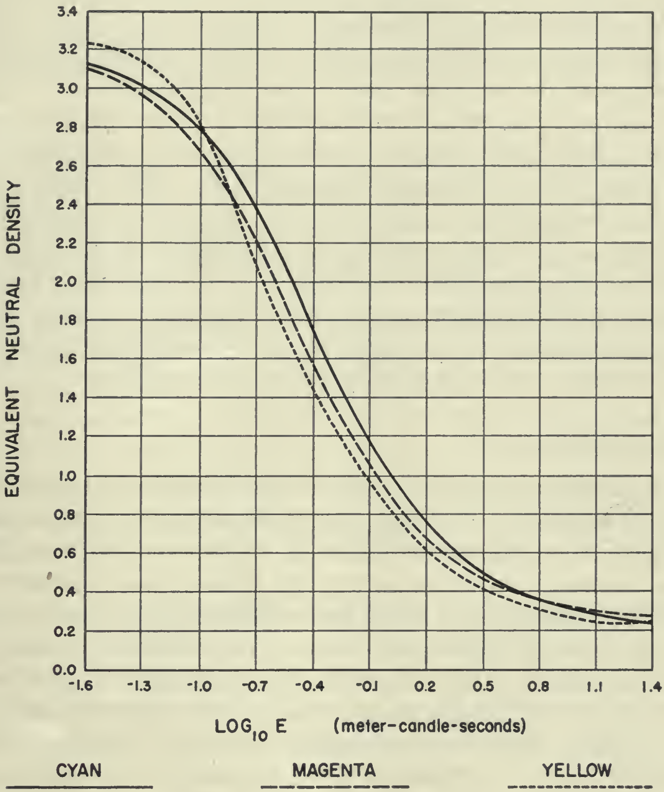

Fig. 5. Analytical density plot of the characteristic curves of a direct-reversal color film. Equivalent neutral densities of the images of a gray scale are shown against the logarithms of exposure.

Figure 5 shows a typical set of characteristic curves of a direct-reversal color film, showing the gray scale densities plotted in units of equivalent neutral density. Instrumental means of obtaining equivalent neutral density analyses of subtractive process images are discussed in later sections of this report.

Equivalent Neutral Printing Densities

For materials intended to be printed rather than viewed, use is sometimes made of an analytical unit called "equivalent neutral printing density."[14] A nonselective gray absorber always has identical red, green and blue printing densities. But because a subtractive-process gray is spectrally selective (as curve N of Fig. 4), its red, green and blue printing densities may be quite different, depending on the portions of the spectrum used in the printing process. But just as a visual gray can always be made up of the subtractive process dyes, so a dye combination can be made up which will have equal values of red, green and blue printing densities. This will be a printing neutral, rather than a visual neutral. All the dye components will have identical equivalent neutral printing densities, rather than identical equivalent neutral (visual) densities. The features of this density unit in printing systems are entirely analogous to those of equivalent neutral density in visual systems, and the advantages of the unit as a descriptive means for printing processes are obvious.

Systematic Errors

Some warnings should be noted in connection with determination of analytical density. In setting up the analytical system, simplifying assumptions are always introduced. Some conditions are always assumed which are not quite met by the process, and it must be realized that combinations of small errors introduced by these assumptions can produce appreciable errors. It is difficult to determine exactly the nature of the independent components of a color process image. Color film images are not made of only three absorbers, the yellow, magenta and cyan dyes usually assumed. There are always, in addition, stains introduced in the manufacture or processing of the film, and there are always surface effects which act like absorbers. Therefore, most analysis systems consider a fourth absorber to be present; in the absence of exact information this is usually considered fixed, i.e., present in the same amount in all images. The characteristics of the remaining components are derived usually from measurements of single-dye images; frequently it is difficult to insure that these single-dye images are really representative of the components of the process. If they are not, errors will appear in the analysis, dependent in kind and magnitude on the type of instrument used. Also, in one type of analysis it is assumed that the equivalent neutral den-

sity of a dye component is a linear function of a spectral density of that component; this is never exactly true although the error of the assumption is frequently small.

It should be kept in mind that analysis into component dyes is only one of a number of possible modes of analysis. In theory, any set of independent variables acting on the processed image can be used as analysis components for that image. In practice, most sets other than the component dyes are too difficult to handle to be of much use.

Integral Densitometry vs. Analytical Densitometry

Both integral and analytical densitometry have important uses in sensitometric operations. Integral densitometry measures performance; analytical densitometry measures composition. For thorough sensitometric description of an image both measurements are required. But both are seldom made. Through experience with a product, the general nature of correlations between composition and performance becomes sufficiently evident that for most tests one measurement is made to serve both purposes. The choice of which kind to make must be answered in each individual case by considering (a) the relative importances of performance and composition data, (b) the apparatus and personnel available for the densitometry, (c) the rate at which determinations must be made, and (d) the importance of high precision of measure and of good agreement among several instruments.

In general, for equal precision of measure, integral density measurements require somewhat less care and simpler apparatus than analytical determinations, and can be made faster. In analytical determinations, inter-instrument differences can be minimized by calibration or by alteration of transfer functions; analytical densities therefore may show better inter-instrument agreement than integral densities. But a set of integral densitometers can be made to agree excellently by applying small systematic adjustments to the readings of each so that the resulting data match a mean result. In spite of these apparent practical advantages of integral densitometry, analytical densitometry also is widely used. This is strong indication that for some purposes the advantages of analytical density data are real and worth the expenditure of considerable effort in their procurement.

V. DENSITOMETER DESIGN PRINCIPLES

The instruments used to determine the density values which describe dye images on color film are generally called "color densitometers." General requirements that must be met by such instruments follow from the principles discussed in the preceding section: For integral densitometry, the spectral response must have specific characteristics that may depend on the intended application; for analytical densitometry, the measurement of each image component must be independent of the amounts in which the other two are present; in both cases, the optical geometry of the instrument must be so arranged that the effects of image scattering can be correctly evaluated. The purpose of this section is to consider the basic components of such instruments, and to review the factors which influence their design. As the art progresses beyond its present unsettled state, specific methods and designs may establish their superiority; meanwhile, no preferred or recommended equipment will be indicated in this report.

Instruments in Current Use

Current practice in the motion picture field includes the general use of three types of instruments. The first and most common type is a three-filter modification of a black-and-white densitometer, as for example the Western Electric RA-1100 densitometer.[15] These instruments measure integral densities. Where the filters are more or less arbitrary, the densities are subject to the limitations discussed in Section IV. By more careful selection of filters, printing densities for specific materials, or colorimetric densities, may be approximated within limits imposed by the over-all sensitivity of the instrument. The Ansco color densitometer[31] employs filters with very narrow transmission bands and thus measures approximately spectral densities at the wavelength of peak transmission of these filters.

Spectral densities at any desired wavelength may be determined with laboratory devices such as the Beckman[17] spectrophotometer and the Cary[18] and General Electric[19] recording spectrophotometers, but these instruments are not designed for use in routine densitometry.

The third type of instrument in use at present is the visual analytical color densitometer described by Evans[13] which is calibrated to yield direct readings of equivalent gray densities. Its use is restricted by the requirement that each of its three dye wedges must have at all

densities spectral absorptions which match the absorption characteristics of the corresponding dye in the film under investigation; thus different sets of wedges are required for different color films. The same limitation applies to the Agfa photoelectric analytical color densitometer described by Schneider and Berger.[20]

Other instruments are in use for special work and laboratory investigations, but these three are the representative classes.

Basic Components

All of these instruments can be regarded as made up of certain basic components. These are briefly listed below; later the most important functional requirements will be discussed for each:

(1) Light sources, which provide the radiant energy used to analyze the dye image,

(2) Spectral selectors, which pass the desired wavelength band of radiation from that source (most commonly a set of filters; alternatively a prism or grating with associated optics and apertures),

(3) Wedges or other attenuators, which are often used to adjust to equality the beam of light transmitted by the specimen and a comparison beam,

(4) Receivers, which detect the radiant energy transmitted by the sample and convert it to a sense perception (visual instruments) or to an electrical signal (photoelectric instruments),

(5) Indicators, which in direct-reading instruments show the density value corresponding to the output signal, or which in null systems show that the measuring and comparison beams have been equated by proper adjustment of the wedges, and

(6) Recorders, which can range from a simple strip chart device attached to an instrument such as the Ansco color densitometer or the General Electric spectrophotometer, up to complex systems which transform the integral densities measured by the photocell into analytical densities and automatically plot either one or both of these sets of densities.

Light Sources

The primary requisite for a light source for color densitometers is that it must produce a sufficient quantity of energy in the desired wavelength regions. In many instruments, it is further required that the output of this source at each wavelength remain constant over long periods of time; if this is not the case, special provisions must be

made to insure stability in both direct-reading instruments and null instruments. Tungsten lamps operated below rated voltage are excellent from the standpoint of constancy of output and have a continuous spectral distribution suitable as a starting point for most instruments. Unfortunately, a high percentage of their energy is put out as heat which must be dissipated. Accordingly, densitometers using tungsten lamps often require forced ventilation of the lamp house and heat-absorbing filters in the measuring beam ahead of the main filter system and the sample.

Other sources of light are under consideration, notably the mercury-cadmium arc. This has the advantage that a considerable portion of its output is concentrated at wavelengths of which three are approximately in the centers of the three spectral regions of most general interest. These wavelengths are considered for use in the standardization of integral densitometry. The efficiency of the mercury-cadmium arc as a source of these particular radiations is much higher than that of tungsten, and the heat problem is accordingly very much less severe. Stability of output is somewhat more difficult to attain with this type of gas discharge lamp than with tungsten lamps, but practical experience indicates that control circuits can be constructed which will hold it within satisfactory limits.

Gas discharge lamps, unlike incandescent lamps, are not concentrated sources; their radiant emission occurs within a rather large volume. In densitometers which use such sources it therefore may be difficult to provide sufficient concentration of energy at the sample plane to permit measurement of small sample areas.

Spectral Selectors: Filters

Filters are used in most integral color densitometers to modify the spectral composition of the beam in accordance with the theoretical requirements stated in Section IV. The simplest specification is to use any set of three filters, of which each isolates somewhat less than one-third of the visible spectrum. The red, green and blue beams so produced establish integral color densities that are peculiar to that specific densitometer and cannot be satisfactorily compared with densities read on other types of densitometer. Nevertheless, such arbitrary three-filter densities may be quite useful for many applications that are within the restrictions pointed out in Section IV.

More stringent requirements must be met by the filters in instruments intended for the measurement of printing densities or colori-

metric densities. The necessary identity (see Section IV) of the products, $J(\lambda)\, e(\lambda)\, S(\lambda)$ and $J'(\lambda)\, e'(\lambda)\, S'(\lambda)$, demands filters that produce in the densitometer a transfer efficiency

$$e'(\lambda) = \frac{J(\lambda)\, e(\lambda)\, S(\lambda)}{J'(\lambda)'S\ (\lambda)}.$$

The quantities $J(\lambda)$ and $e(\lambda)$ are determined by the printing system, $S(\lambda)$ is a property of the print stock, while $J'(\lambda)$ and $S'(\lambda)$ are characteristics of the source and receiver of the densitometer. These last two quantities are generally fixed by other design considerations, so that the function $e'(\lambda)$ is rigidly specified. The selection of a combination of filters that yield a reasonably close approximation to the required spectral properties is a rather challenging problem for the instrument designer; when the desired filter cuts are achieved, the efficiency is often so low that the sensitivity of the radiation receiver is insufficient to measure the transmitted light with the necessary accuracy.

Similar problems are encountered in the selection of filters for instruments that are to yield approximate spectral density measurements. Here the pass-bands will be made as narrow as feasible, consistent with the requirement of sufficient output energy to permit accurate measurement. The location of the peak wavelengths for measurements of this type is currently under consideration by the Committee on Still Photography, Z38, of the American Standards Association. At certain specific wavelengths, a narrow spectral composition of the measuring beam can be produced with fairly high efficiency by using a "line source," such as a mercury-cadmium arc, together with filters that isolate the strong individual lines in the spectra of these sources.

An important practical requirement for all filters used in color densitometry is that they should be stable. Their spectral characteristics must not change as a result of exposure to the heat, humidity, and radiant energy that they will encounter in the densitometer. As far as possible, glass filters should be used; in all cases the beam transmitted by the filters should be restricted to the smallest amount of energy which will meet the requirements of the system. Filters should be protected from infrared as mentioned earlier, and, equally important, from ultraviolet in the case of sources which emit considerable energy in that region. Fluorescence in any of the filters or in the sample introduces special problems that must be analyzed before

density readings made with them are accepted as representative of the film under normal conditions of use.

Spectral Selectors: Dispersion Systems

Spectral dispersion by prism or diffraction grating provides an alternative method of modifying the spectral composition of the measuring beam in integral color densitometers. In these instruments energy from the light source is spread out into a spectrum from which certain wavelength regions can be selected by masks or slits. At each wavelength, λ, the height of the opening in the mask controls the amount of radiation transmitted by the mask, so that any spectral transfer function, $e'(\lambda)$, can be established by proper shaping of the opening in the mask. Densitometers based on this method of spectral selection are therefore readily adaptable to the measurement of any desired type of printing or colorimetric density, including luminous density.

If only a single wavelength band is permitted to pass through a narrow slit, the resulting radiation is said to be monochromatic and such radiation may be selected at any desired wavelength by proper positioning of the slit. As the slit is widened, more radiant energy is transmitted, but the spectral purity of the beam suffers. If such an instrument is used with a light source that has a continuous spectrum, and is so arranged that spectral densities can be read at any wavelength, it is called a spectrophotometer. A "spectrophotometric curve" showing the spectral density of a photographic image at all wavelengths is a complete and basic description of the absorption properties of that image. A spectrophotometer of adequate sensitivity is the ideal laboratory instrument, but it suffers from the disadvantage that its use is too complicated and time-consuming for routine sensitometry. The effects of scatter must be kept in mind; spectrophotometer results are strictly applicable only to situations in which scattered radiant energy is evaluated in the same way as in the spectrophotometer.

Wedges

Wedges are variable absorbers used to reduce the intensity or change the color of the radiation transmitted by the optical system of a densitometer. They are generally found in visual instruments. In electronic densitometers it is often easier to accomplish the equiv-

alent attenuation by electrical means, but for certain purposes wedges may also be employed. The best known form of wedge is that found in the Capstaff visual densitometer[21] for black-and-white film. This is a circular glass plate carrying an arc-shaped silver image whose density varies from a minimum value slightly above zero to a maximum value above 3.0. The density variation is approximately linear with the angle through which the plate is rotated.

Similar gray wedges can be made of gelatin containing gray dye mixtures or colloidal graphite. Yellow, cyan and magenta wedges containing graded amounts of the dyes used in specific color processes are used in the direct analytical densitometry of those processes.

The manufacture of wedges is difficult, and calibration of the individual wedges is necessary for precise work. Such calibrations must be periodically checked to make sure that the wedge characteristics have not changed as a result of fading or other effects. In dye wedges used for analytical color densitometry, careful spectrophotometric checks must be made to insure that the spectral transmittance characteristics of the wedge are at all densities identical with those of the corresponding dye in the photographic image. The fact that certain types of photoelectric instruments do not require wedges is a distinct point in their favor.

Receivers

The receiver for a visual densitometer is the observer's eye. Care must be taken to insure that the operator has no abnormalities of color vision. This is particularly important in cases where the observer's task involves the matching of two fields that are not spectrally identical. Operator fatigue tends to reduce the accuracy of photometric and colorimetric matches, and visual instruments are therefore not suitable for the evaluation of large quantities of test images.

Receivers for electronic instruments include many of the usual types of photocells or photo-multiplier tubes. Since most of the densitometry in a color process occurs in the visual region of the spectrum, receivers which are sensitive to infrared or ultraviolet are required only for special purposes, such as sound track or integral silver mask analysis. In fact, the sensitivity which all photoelectric surfaces tend to have in these regions is usually a disadvantage, and great care must be taken in the filter system to insure that the cell is receiving only those wavelengths which it is desired to utilize. This is

a particularly difficult problem in the case of filters made from dyes, since almost without exception their infrared transmission is high, and even the S-4 surface has considerable residual sensitivity in the near infrared region. Infrared absorbing filters are therefore included in the optical path of most photoelectric color densitometers. These may be glass, such as Corning 9780, or liquid, such as cupric chloride solution. These near infrared absorbers should not be confused with heat-absorbing filters which usually are also included in the optical path.

The photocell is associated with an amplifier whose output operates an indicating instrument or a recorder. These amplifiers are varied in type, depending on the functional design of the densitometer. In the Ansco instrument the radiant energy transmitted by the sample arrives on the photocell at a constant rate proportional to the transmittance of the sample. The circuit associated with the photo-multiplier tube receiver automatically controls its dynode voltage in such a manner that the photo-multiplier tube anode current is held constant regardless of specimen density. The output of the instrument is measured in terms of dynode voltage which is essentially linear with specimen density. In the Western Electric instrument, radiant energy from an interrupted beam arrives at the photocell as an alternating signal of which the amplitude is proportional to the transmittance of the sample. Here a two-element vacuum phototube and a normal a-c amplifier produce a linear response proportional to transmittance. This is converted to density by a nonlinear indicator.

A somewhat simpler situation exists in instruments in which the energy in the sample beam is adjusted by an optical attenuator until it matches a fixed comparison beam. If the two beams are directed onto the photocell in rapid alternation, a sensitive a-c amplifier will detect any small difference between the energy in the two beams. Zero output will be obtained only when the beams are matched. When this condition is attained, the density of the sample is read from a scale which measures the position of the optical attenuator. Densitometers, such as the General Electric spectrophotometer, which utilize this design principle, are often called *null* instruments.

In general, the combination of receiver and amplifier should have the maximum of sensitivity in the desired wavelength band and minimum sensitivity elsewhere with the maximum degree of stability possible. This is particularly important in instruments which

are not of the null type, as any change in over-all sensitivity of these units produces a shift in calibration.

Indicators

In photoelectric color densitometers, the desired information about the sample is contained in an electrical signal which must be conveyed to the observer by some sort of indicating or recording device. Where the amplifier puts out a signal that is directly proportional to density, an ordinary electrical measuring instrument will show a deflection proportional to density. The scale on such a meter can be marked directly in density. If the amplifier output is proportional to transmittance, the scale of the same type of meter might be divided into logarithmic intervals so as to yield density readings. However, a scale like that would be so closely spaced at one end that the precision of high *density* readings would be low. This difficulty can be minimized by using electrical meters with special nonlinear movements in which the deflection is approximately proportional to the logarithm of the input signal. Such meters are generally used over a 10:1 signal range, so that they cover a density interval of 1.0. Signals that exceed this range are reduced by factors of 10, 100 or 1000 through electrical or optical attenuators, so that densities in the ranges 0 to 1, 1 to 2, 2 to 3, and 3 to 4 can all be read by appropriate settings of a range control.

In null instruments, the electrical indicator serves only to show that a balance has been attained between two beams. The principal requirement is high sensitivity so that even a small amount of unbalance may be detected. The densities themselves (or readings from which they can be computed) are obtained from scales attached to the wedges or other attenuators which are used to establish balance between the two beams. An attempt is generally made to provide a scale that is approximately linear with density over the range of the instrument.

Recorders

Recorders can be attached to any electronic color densitometer. The Cary and General Electric spectrophotometers are normally equipped with recording means. Recording is especially desirable in spectrophotometers because these instruments can determine spectral densities at all wavelengths within a large spectral range. These density values can be shown as functions of wavelengths on spectro-

photometric curves. On a non-recording instrument many separate readings would have to be made and subsequently plotted to obtain such a curve. By the use of a recorder it can be plotted directly by the machine.

The Ansco instrument is so designed that an ordinary Brown one-milliampere linear recorder can be directly attached. Density recorders generally can be thought of as modifications of recording power level indicators, such as are standard in the communications field. Their application to the particular circuit of any densitometer can be worked out for each case by normal electrical engineering methods, although the range and stability requirements may be more severe than for the usual acoustical applications.

Geometrical Design Factors

The scattering of radiation by the dye image in color films has an important influence on the effective absorption of a film sample in different optical systems. This circumstance has already been discussed in Section IV where it was pointed out that evaluation of the scattered radiation in the color densitometer should not be substantially different from that in the optical device in which the film is to be used. It was further indicated that the use of apertures larger than the minimum required for acceptance of the cone of principal scattering would involve only small errors.

The instruments now available exhibit considerable variation in the mode of illumination of the sample, and in the arrangement used to collect the transmitted radiation. The suitability of any particular geometrical design for a specific use can be checked by tests in which density readings of the given color film materials are compared with its performance in the optical system (printer, projector, viewer) for which it is intended.

The only geometrical arrangement that has so far been standardized is that which measures *diffuse* transmission density. This is defined and techniques for its measurement are specified in American Standard Z38.2.5. The introduction to this standard points out the possibility of applying corrections to the calibration of *any* type of densitometer so that it will yield diffuse density values for any *single* type of photographic material. In general, new corrections must be determined if accurate readings are desired on a different photographic material. In color products, the correction factor may also vary with

the image color in any one material. For example, the correction factor may be larger for yellow images than for blue ones.

Systems for Integral Densitometry

Color densitometers are functional assemblies of the basic components which have been discussed. The selection or design of specific components and their integration into an effective system constitute the task of the instrument designer. Without considering structural, optical or electrical details which may be seen in published

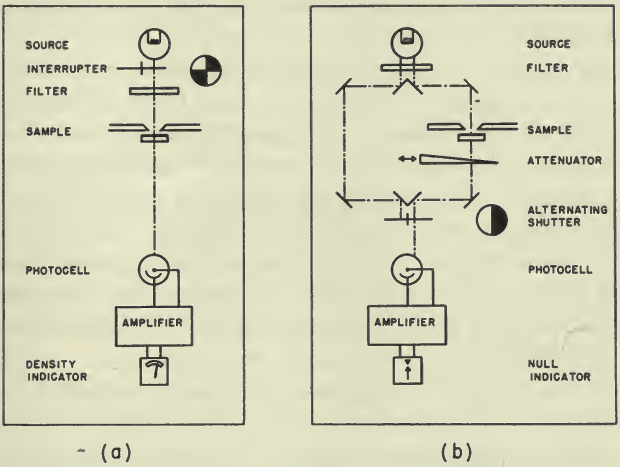

Fig. 6. Schematic diagrams of basic densitometer designs: (a) direct-reading instrument, (b) null instrument. In a direct-reading instrument, the photocell output is used to measure the density of the sample. In a null instrument, the photocell serves only to indicate balance between beams; the density of the sample is measured by the attenuator.

descriptions of current instruments or obtained from their manufacturers, the remainder of this section will deal with some of the general features of complete densitometer systems.

Integral color densitometers may be subclassified in numerous ways; one of the most significant distinctions is that between direct-reading instruments and null instruments. This fundamental difference which has already been referred to in the discussion of basic components is schematically illustrated in Fig. 6.

A direct-reading instrument performs a measurement of the radiant energy transmitted by the sample. Usually, this measurement is

preceded, at the time of calibration, by a measurement of the radiant energy incident upon the receiver with no sample in the beam. The instrument is adjusted until the density reading obtained with no sample is zero; subsequent measurements with film samples in the beam are then made with respect to that reference level. The distinguishing features of direct-reading instruments are the single-beam optical system and the direct quantitative evaluation of transmitted radiant energy as a fraction of (or density difference from) a previously established no-sample reference level. The human eye is not capable of performing direct quantitative measurements of radiant energy, and direct-reading instruments are therefore based on photoelectric receivers.

In a typical direct-reading instrument, shown schematically in Fig. 6a, the primary output of the receiver may be an alternating signal produced by an intermittent ("chopped") measuring beam. After amplification and rectification, a d-c signal proportional to transmittance is obtained. By applying this signal to a logarithmic meter, a deflection approximately proportional to density is produced as final indication. Other systems of obtaining a uniform density scale have been used with success. The method of producing a logarithmic output signal by using a photo-multiplier tube in a special circuit has already been mentioned in discussing basic components.

In a null instrument, the receiver serves only to establish the equality of response to the radiant energy contained in two separate beams, and, alternatively, to provide a sensitive indication of mismatch between these beams. Equality of response is brought about by calibrated reduction of the response from one of these beams, usually by means of optical attenuators (silver wedges, polarizing prisms, variable apertures). As shown in Fig. 6b, such an attenuator may be in the same beam as the sample; the combined absorption of sample and attenuator reduce the radiant energy until the response is identical with that from a fixed comparison beam. Or the attenuator may be in the other beam, so that the response from the comparison beam is reduced until it matches that of the sample beam. In either case, the density of the sample is read or computed from a scale indication on the attenuator. In situations where the spectral quality of the energy is identical in the two beams, as in the measurement of spectral densities, the eye may serve as a simple and sensitive receiver, although here too photoelectric instruments will be preferred for routine operations.

Systems for Analytical Densitometry

The direct measurement of analytical densities is based on the principle that the absorption of the dyes in the film sample can be matched by the combined absorption of three wedges, each of which contains varying known amounts of one of the three dyes of the process in question. The simplest situation is shown in Fig. 7 where the left beam contains the sample, and the right beam the set of wedges. When each of the wedges is set to its proper position, their combined absorption will match that of the sample, and the two beams will be indistinguishable. If the eye is to be used as detector, the two beams will be presented for observation in a split field optical system. The task of the observer is then similar to the operation of a

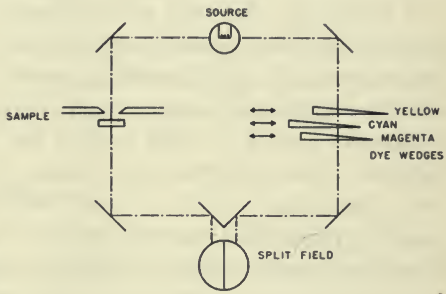

Fig. 7. Schematic diagram illustrating the principle of an analytical color densitometer. The absorption of the sample in the left beam is matched by the combined absorption, in the right beam, of three wedges, each containing one of the three process dyes.

visual colorimeter: The three wedge adjustments must be manipulated until a color match is obtained. When this is achieved, the position of the wedges will indicate yellow, magenta and cyan analytical densities, or, with proper calibration, the corresponding equivalent neutral densities.

An instrument based on this principle of operation is properly described as a null instrument, but it differs in one fundamental point from the null instruments used for the measurement of integral densities. In the former instruments, equality of response could be secured by a single adjustment; in the present case we have three independent variables. In integral densitometers, three numbers describing the color film image are obtained by three successive operations with three measuring beams differing in spectral quality. Each of the three operations involves only one variable. In direct analytical densitometers, three numbers providing an alternative

description of the color film image are obtained in a single operation involving three variables.

Therefore, if the eye is to be replaced by a photoelectric receiving system, this system, like the eye, must be capable of judging the equality of two beams with respect to three parameters. In the instrument described by Schneider and Berger[20] this is accomplished by inserting red, green and blue filters before the photocell in rapid alternation, so that the two instrument beams are effectively compared first by a red-sensitive photocell, then by a green-sensitive photocell, then by a blue-sensitive photocell. If in each case the response from the sample beam is equal to the response from the wedge beam, the two beams are satisfactorily matched. The three filters used with the photocell will be selected to provide maximum sensitivity in the detecting system to small errors in the setting of the wedges.

A somewhat different arrangement of the wedges is used in the visual analytical densitometer described by Evans.[13] This again is a null instrument, but the wedges are in the same beam as the sample, and the comparison beam is fixed. This has the great advantage that the appearance of the split field at the match point is the same for all samples. The fixed comparison beam corresponds roughly to a sample with maximum yellow, magenta and cyan dye deposits. When a sample with smaller amounts of dye is inserted, the balance is restored by adding the absorption of the dye wedges. The amount so added yields an inverse indication of the amount present in the film sample. A further feature of the Evans instrument is the presence of a silver wedge which can be used to substitute a nonselective silver deposit for a gray combination of wedge dye deposits. In the evaluation of nearly gray film samples, this substitution circumvents errors which tend to occur at high densities in dye wedges.

The crucial component of all direct analytical densitometers is the wedge set. The preparation of suitably graded wedges in which the dye images are and remain strictly equivalent to those encountered in actual film samples is an extremely difficult task which must be separately undertaken for each color process to which the densitometer is to be applied. Once such wedges are available, analytical densitometers provide descriptions of the film image composition in terms that are particularly valuable in investigative work.

VI. TRANSFORMATIONS BETWEEN INTEGRAL AND ANALYTICAL DENSITIES

Instruments for the measurement of integral and analytical color densities have been separately discussed in the preceding section. The difficulties encountered in the direct determination of analytical densities suggest the possibility of utilizing the relationship between integral and analytical densities to compute the latter from the former.[12,23] Where this course is adopted, samples are read on an instrument that yields integral spectral densities. For many purposes, especially in routine control, these are used directly; for other applications, where description in terms of the amounts of the individual dyes is more useful, the integral spectral densities are "converted" to analytical densities by computation.

The general nature of the relationship between these two types of color density has already been considered in Section IV. The problem now is to reduce this to a quantitative formulation which is suitable for routine computation.

Densities of Superimposed Dye Images

Figure 8 shows the spectral densities of the yellow, magenta and cyan dye deposits in a sample of multilayer film. This sample differs from the one illustrated in Fig. 4, both in the kind and in the amount of the dyes it contains, but the diagrams are similar in showing the variation of spectral density with wavelength for each of three components of a subtractive image. The sample shown in Fig. 8 is a gray sample; the yellow, magenta and cyan dyes produced in this process are present in just the right amounts to make the sample appear achromatic in a given reference illuminant (3000 K in the case of Fig. 8). The gray image which they form has a visual density exactly equal to 1.00.

This appearance is the result of the combined action of the three component dye images on the radiation passing through the film. At each wavelength, each of the dyes acts independently of the others in absorbing radiation, and the total density at each wavelength is equal to the sum of the densities of the components. At 535 mμ, for example, the density of the yellow dye deposit is 0.09; that of the magenta, 0.76; and that of the cyan, 0.17. The total density, at 535 mμ, of the image is $0.09 + 0.76 + 0.17 = 1.02$. This total or "in-

tegral" spectral density of the three superimposed dye components is the quantity plotted as the curve marked N in Fig. 8; it is identical with the integral spectral density of the image that would be determined in a spectrophotometer. This wavy horizontal curve can thus be alternatively thought of as a spectrophotometric curve showing the integral spectral densities of the gray image, or as a plot, wavelength by wavelength, of the sum of the spectral densities of the yellow, magenta and cyan components of the image.

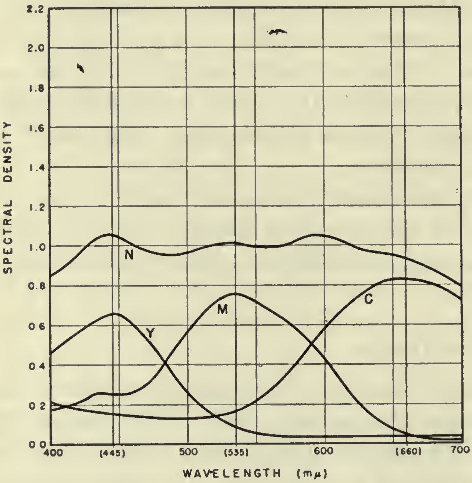

Fig. 8. Spectral densities of yellow (Y), magenta (M) and cyan (C) dye images obtained in a subtractive color process. Superposition of these images yields an image (N) that appears gray and has a visual density of 1.00.

Table II. Spectral Densities of the Dye Image of Fig. 8

(1) λ	(2) N	(3) Y	(4) M	(5) C
445	1.06	0.66	0.24	0.16
535	1.02	0.09	0.76	0.17
660	0.93	0.04	0.05	0.84

When the complete dye image is to be described by integral spectral densities, three such densities, at three different wavelengths, are generally sufficient. Table II lists three such wavelengths in Column 1, and the corresponding integral spectral densities in Column 2. The remaining columns show the individual spectral densities of the dyes. The choice of the three particular wavelengths has been arbitrary. They coincide with the absorption peaks of the three dyes, but this is not a rigid requirement. In practice, any three wave-

lengths in the regions of principal absorption of the three dyes will be acceptable, and plans are under discussion to adopt three standard wavelengths for use in all instruments.

Density as a Function of Dye Concentration

A sample with denser dye images is shown in Fig. 9. Here the yellow dye deposit has been increased until its spectral density at 445 mμ is just twice as large as in the earlier sample, *i.e.*, 1.32 instead of 0.66. If the yellow dye deposit in this process behaves in accordance with elementary theory, its spectral density at all other wavelengths will also be exactly twice its former value, and the complete yellow

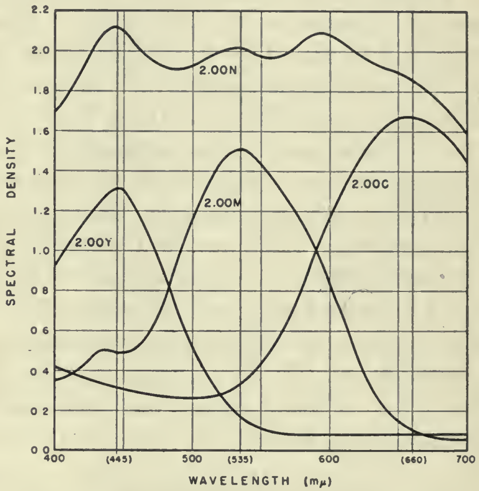

Fig. 9. Spectral densities of yellow, magenta and cyan dye images that have exactly twice the absorption of the images of Fig. 8. Superposition of these components produces an image whose spectral densities are exactly twice those of N in Fig. 8, but this image is not exactly neutral nor is its visual density exactly 2.00.

curve of Fig. 9 is simply the result of multiplying by two all the ordinates of the yellow curve of Fig. 8.

The requirement here involved is generally stated by saying that the dye deposit obeys *Beer's Law*, although strictly speaking, it is only necessary that the spectral density, $D(\lambda,k)$, as a function of wavelength λ and concentration k can be represented as the product $f(\lambda)\cdot g(k)$ of two separate functions. Even this less stringent requirement is followed only approximately by actual dye deposits.

If the magenta and cyan deposits are also assumed to follow this relationship, and if their spectral densities are similarly multiplied by two, the spectral densities of all three dye images and their sum will be as shown in Fig. 9. The shape and position of the top curve of

Fig. 9, which has been obtained by adding the spectral densities of the three dye components, suggests that the film sample it represents will be approximately a gray of density 2.0. The elementary theory of analytical densitometry assumes that it will be strictly achromatic in the reference illuminant, and that its density will be exactly 2.00. This is not rigorously true, even for dye deposits which follow Beer's Law. The departures for a number of spectral absorption curves have been investigated by MacAdam[22]. In actual photographic processes these departures are generally considered so small as not to interfere with the usefulness of densities derived on the basis of elementary theory.

The analytical densities of the dye deposits shown in Figs. 8 and 9 can be expressed on various scales, in accordance with principles discussed in Section IV. For example, the spectral analytical densities of the magenta deposits at 535 mμ are 0.76 and 1.52, respectively. The more conventional scale is that of "equivalent neutral densities." These have been so defined that the yellow, magenta and cyan deposits shown in Fig. 8 each have an equivalent neutral density of 1.00 (since their superimposed absorptions constitute a visual gray of that density). It follows for this particular set of three dyes, and for this set only, that a yellow deposit of equivalent neutral density 1.00 has a spectral density of 0.66 at 445 mμ. The yellow deposit shown in Fig. 9 has an equivalent neutral density of 2.00, and a spectral density of $2 \cdot 0.66 = 1.32$. In general, a yellow deposit of equivalent neutral density Y will have, at 445 mμ, a spectral density of $0.66 \cdot Y$. Analogous relations apply to the other two dyes, and to other wavelengths.

Integral Densities from Equivalent Neutral Densities

Once the equivalent neutral density is known of each component in a composite specimen of the product illustrated in Fig. 8, it becomes a simple matter to obtain the integral density curve from the data represented by Fig. 8. It entails merely multiplying the ordinates of the spectral density curve of each component, as shown in Fig. 8, by its respective equivalent neutral density, and plotting the summation of the resulting densities at each wavelength. To give an example, let the equivalent neutral densities of a composite sample of this process be 2.00, 1.50 and 1.10 for the yellow, magenta and cyan, respectively. Then at 445 mμ, the density of the yellow component would be $0.66 \cdot Y = 0.66 \cdot 2 = 1.32$; that of the magenta component would be $0.24 \cdot M = 0.24 \cdot 1.50 = 0.36$; and that of the cyan component would be $0.16 \cdot C$

$= 0.16 \cdot 1.10 = 0.18$. The integral spectral density at 445 mμ would therefore be:

$$D_{445} = 0.66Y + 0.24M + 0.16C = 1.86.$$

The corresponding relations at 535 mμ and 660 mμ are:

$$D_{535} = 0.09Y + 0.76M + 0.17C = 1.51.$$
$$D_{660} = 0.04Y + 0.05M + 0.84C = 1.08.$$

In a similar manner, the integral densities at all other wavelengths in the spectrum may be calculated; the result is shown in Fig. 10.

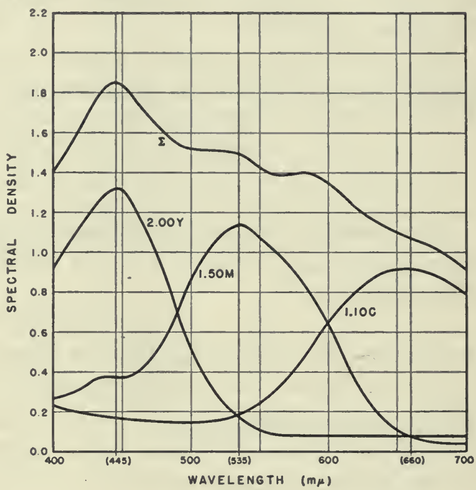

Fig. 10. Spectral densities of a non-gray image (Σ) formed by varying the amounts of the dyes in the gray image of Fig. 8. The equivalent neutral densities of this image are 2.00 (yellow), 1.50 (magenta) and 1.10 (cyan).

An integral color densitometer reading the spectral densities of the composite sample at wavelengths 445 mμ, 535 mμ and 660 mμ would indicate the densities shown in the equations just cited. If, for simplicity these are designated as "blue", "green" and "red" densities D_b, D_g, and D_r, the final relations for computing integral spectral densities from equivalent neutral densities are, for this particular dye system and these particular wavelengths:

$$D_B = 0.66Y + 0.24M + 0.16C,$$
$$D_G = 0.09Y + 0.76M + 0.17C,$$
$$D_R = 0.04Y + 0.05M + 0.84C.$$

Equivalent Neutral Densities from Integral Densities

The reverse procedure is not as simple, but it is nevertheless straightforward. In order to obtain the equivalent neutral density of

each component in a composite specimen from integral density measurements, the integral density of the sample must be determined at three different wavelengths, preferably in the region near maximum absorption of each component.

It is assumed that data corresponding to those shown in Table II are available for the dye system in question; these basic constants are the spectral densities, at the three wavelengths of the integral densitometer, of single dye deposits of equivalent neutral density 1.00. Let b_y, g_y and r_y designate the blue, green, and red densities of the unit yellow deposit, with corresponding abbreviations for the magenta and cyan constants.

The conversion equations derived in the preceding sections can then be written in the more general form:

$$\begin{aligned} D_B &= b_y\, Y + b_m\, M + b_c\, C \\ D_G &= g_y\, Y + g_m\, M + g_c\, C \\ D_R &= r_y\, Y + r_m\, M + r_c\, C. \end{aligned}$$

This system of three simultaneous equations may be solved for the three unknowns Y, M, and C, by ordinary algebraic procedures.[24] The solution is:

$$\begin{aligned} Y &= a_{11}\, D_B + a_{12}\, D_G + a_{13}\, D_R \\ M &= a_{21}\, D_B + a_{22}\, D_G + a_{23}\, D_R \\ C &= a_{31}\, D_B + a_{32}\, D_G + a_{33}\, D_R. \end{aligned}$$

The nine new constants are:

$$a_{11} = \frac{1}{N}(g_c\, r_m - g_m\, r_c);\ a_{12} = \frac{1}{N}(b_m\, r_c - b_c\, r_m);\ a_{13} = \frac{1}{N}(b_c\, g_m - b_m\, g_c);$$

$$a_{21} = \frac{1}{N}(g_y\, r_c - g_c\, r_y);\ a_{22} = \frac{1}{N}(b_c\, r_y - b_y\, r_c);\ a_{23} = \frac{1}{N}(b_y\, g_c - b_c\, g_y);$$

$$a_{31} = \frac{1}{N}(g_m\, r_y - g_y\, r_m);\ a_{32} = \frac{1}{N}(b_y\, r_m - b_m\, r_y);\ a_{33} = \frac{1}{N}(b_m\, g_y - b_y\, g_m),$$

where

$$N = b_y\, g_c\, r_m + b_m\, g_y\, r_c + b_c\, g_m\, r_y - b_y\, g_m\, r_c - b_m\, g_c\, r_y - b_c\, g_y\, r_m.$$

This operation can be stated more concisely in the notation of matrix algebra, where the nine coefficients are simply elements of a transformation matrix. We are here primarily interested in the fact that the previous equations can be solved to provide a simple system for the calculation of equivalent neutral densities from measurement of integral spectral density. For the dye system of Fig. 8, the transformation equations are:

$$\begin{aligned} Y &= 1.59\ D_B - 0.50\ D_G - 0.20\ D_R \\ M &= -0.17\ D_B + 1.39\ D_G - 0.25\ D_R \\ C &= -0.07\ D_B - 0.06\ D_G + 1.22\ D_R. \end{aligned}$$

To illustrate the use of these equations, we consider the sample of Fig. 10. An integral densitometer reading spectral densities at 445, 535 and 660 mμ would indicate for this sample the values plotted in the top curve; $D_B = 1.86$, $D_G = 1.50$ and $D_R = 1.07$. Substitution of these numbers into the equations above yields the correct answers: $Y = 2.00$, $M = 1.50$, and $C = 1.10$.

Non-monochromatic Integral Densities

Throughout this treatment, it has been assumed that the integral densities have been determined on instruments reading monochromatic spectral densities. Most practical instruments achieve only an approximation of this condition; even where a special effort is made to use narrow-band filters, the bandwidth is often more than twenty millimicrons. For such instruments, the transformation coefficients b_y, b_m, etc., are no longer the spectral densities of Table II, but rather the corresponding density readings actually obtained on the instrument for single dye deposits of equivalent neutral density 1.00. However, the validity of transformation equations derived in this manner becomes more and more questionable as the filter bands widen. These linear equations were based on the principle that the individual densities of superimposed dye deposits could be simply added to give the integral density of the combination, and this is not valid for integral densities obtained with wide filters. In the best narrow-band instruments, the departures are relatively small; whether they are within tolerable limits depends on the application. In any given situation, the calculated analytical densities should be compared with known values for a series of samples which cover the range of densities and colors over which the calculations are to be applied.

Modified Conversion Equations

A second complication arises from the fact that the absorption of radiant energy in an actual film sample cannot be entirely accounted for by the absorption of the yellow, magenta and cyan dye images. Additional radiation losses occur in the film base and in non-image "stain" as well as by reflection. To a first approximation, errors from these losses can be corrected by the addition of small constant terms to the transformation equations, which then assume the form:

$$\begin{aligned} Y &= a_{11} D_B + a_{12} D_G + a_{13} D_R + a_{14}, \\ M &= a_{21} D_B + a_{22} D_G + a_{23} D_R + a_{24}, \\ C &= a_{31} D_B + a_{32} D_G + a_{33} D_R + a_{34}. \end{aligned}$$

The values of these constant terms can be determined by trial. Since the equivalent neutral densities of gray samples are equal to their luminous densities, gray samples offer an accurate means of trial. Their measured densities are compared with their computed equivalent neutral density values. The computation equations are then altered by addition of the constants required to minimize errors. This empirical method of determining the additive constants a_{14}, a_{24} and a_{34} also provides a first-order correction for the departures shown by actual materials from the theoretical relationships discussed under *Density as a Function of Dye Concentration*, above.

Further improvement in the calculation of analytical densities might be achieved by the use of nonlinear transformations, but the added computing burden would make it difficult for such a procedure to compete in utility with the direct measurement of analytical densities.

Computing Devices

The large-scale use of computed analytical densities in color sensitometry is dependent on rapid and economical procedures for the solution of the linear transformation equations which have been discussed. Standard desk calculators with provision for accumulative multiplication are well suited to this task. Alternatively, it is possible to use electrical networks for the solution of these equations. In the latter type of instrument, the values of D_R, D_G and D_B are put in as shaft rotations, and this operation could, in principle, be directly performed by the integral densitometer in cases where the integral densities themselves are of no interest. In situations where only few data are to be handled and the required precision is not high, nomographs may be used to advantage.

VII. INTERPRETATION OF SENSITOMETRIC RESULTS

The primary results of the ordinary procedures of color sensitometry are sets of color density values that describe the images produced by known exposures. These color densities vary with changes in film, with processing changes, and with many other factors which must be evaluated and controlled in the practice of color photography. The interpretation of the results in terms of these many factors is the final step in color sensitometry.

This step, like all interpretation of technical data, will be governed by the specific purpose at hand. In research and development work leading to new materials and processes, the results of sensitometry are used in studying the effects of manufacturing and processing changes on fundamental characteristics such as speed, gradation, latitude, color reproduction and keeping properties. The present report will not attempt to deal with this wide range of problems which are of interest to only a small group of research and manufacturing establishments.

In the domain of the motion picture laboratory, the range of problems is narrower, but the role of color sensitometry is no less important. The adjustment and control of processing and printing operations require long-range as well as day-to-day decisions which must be based on the results of sensitometric tests. These are the purposes with which the present discussion of data interpretation will be primarily concerned.

Since this subject involves purposes as well as facts, it is inherently more controversial than the material in previous sections. The principles here discussed are tentative; their validity can be established only as more experience accumulates in this relatively young field.

Process Adjustment

Successful operation of a color film process is usually accomplished in two stages. In the initial period of operation, the process is intentionally changed after each trial run until the results are judged satisfactory. Once the aim point has been established, the objective will be to produce results repeatedly with minimum departure from

this aim. The first stage will be called *adjustment*, and the second *control.*

Adjustment of the process normally calls for evaluation as discussed in Section I. It will be the function of color sensitometry to provide an objective description of process performance. This calls for interpretation of the results in terms of the application for which the film is intended. If the film is a positive intended for screen viewing, the sensitometric results must be interpreted in terms of visual appearance; if, on the other hand, the film is a camera original or an intermediate negative or positive, the evaluation must be made in terms of printing characteristics.

Evaluation for Viewing

A print process yielding positives for screen projection will generally be adjusted by considering the over-all quality of the reproduction. The objective will be to produce a pleasing likeness of the original scene; if the camera original has certain systematic defects, the print process will be adjusted, wherever possible, to compensate for them. Subjective quality judgments of representative scenes will be an essential factor in this adjustment; the corresponding sensitometric data will show final print densities as functions of exposure of the camera original. For this purpose, a camera film carrying a sensitometric image will be printed on the print film by the normal printing procedure.

Such "over-all" reproduction data are the primary measurements in adjustment. They are often supplemented by direct print film sensitometry, in which print densities are studied as a function of print exposure, independent of the camera film. These separate measurements on the print process can be made with somewhat higher precision than the over-all measurements. In some cases, the aim point for the adjustment of a print process is already known in terms of direct print sensitometry; the actual adjustment can then be made by print sensitometry without recourse to over-all measurements or picture quality judgments. In other cases, clues to specific print process changes may be more apparent in direct print sensitometry than in over-all measurements. But wherever the aim point is in question it is sound procedure to return to the primary method of evaluating, by measurement and by subjective judgment, the over-all quality of the reproduction.

Gray Scale Exposures

Two basic requirements are often stated in discussing the "over-all" rendition of color processes: A gray tone scale in the original scene must be rendered as a visually gray tone scale in the finished image, and the image tone scale must reproduce the contrast of the original scene. Both criteria are open to qualification in specific processes. In some processes, optimum picture quality, as established by careful judgments with many observers, is achieved under conditions that do not reproduce a gray scale as a series of visual grays. Similarly, the imperfections of many color processes are such that a more pleasing picture is obtained when the over-all contrast is increased above unity. In such cases, the saturation of the colors in the reproduction will be more nearly correct, but the contrast in the gray scale will be excessive. If these limitations are kept in mind, the original requirements may still serve as a useful guide for the initial adjustment of a print process. They can be combined into a single rule: *A gray scale in the original scene should be reproduced as a similar gray scale in the final image, both with respect to color balance and contrast.*

While no process can be successful if it departs very far from this condition, it must be realized that this is by no means a *sufficient* condition for satisfactory reproduction, and that non-gray exposures must be used to supplement the usual gray scale sensitometry.

In a process in which gray subjects are reproduced as approximately gray images, the contrast, density range, and similar reproduction characteristics of the gray scale can be interpreted by the methods of black-and-white sensitometry. For this purpose, the gray or nearly gray images should be read on an integral densitometer which reads luminous densities (see Section IV). Such a densitometer will yield results in agreement with the brightness evaluations that would be made by a normal observer in a visual densitometer. To obtain the over-all reproduction characteristics, these print densities must be plotted against the logarithms of the sensitometer exposures that were given to the camera film.

While the individual steps of the gray scale reproduction in the print may be sufficiently close to a visual gray to permit over-all evaluation by luminous densities, the color of each step usually departs from gray, and the magnitude and direction of these departures are important characteristics of the process. In fact, the adjustment of these differences is one of the major tasks of process adjustment.

Integral Color Densities

Three density values are necessary to describe the color of each image, and for images that are to be viewed on the screen these densities should, in principle, be the colorimetric densities described in Section IV. These are the only densities directly related to the international standard scales on which the color of the images would be correctly described. In practice, however, it has been found sufficient to demand that the density numbers used for this purpose should satisfy these simpler requirements: (a) The three densities describing a gray image should be equal, and (b) in describing a non-gray image, the differences among three unequal densities should give an approximate indication of its hue and saturation.

Arbitrary three-filter integral densities will not satisfy the first of these requirements; neither will spectral densities. For an accurately gray image in a typical process, Fig. 8 shows spectral densities of 1.06, 1.01 and 0.93. For a given process, it would be possible, of course, to select reading wavelengths such that equal densities would correspond to a gray at least at one density level. Alternatively, it would be possible to compute, for other wavelengths, multiplicative scale factors which would so convert the original densities that equal numbers would correspond to a gray at least at one density level. In direct-reading densitometers, this multiplication might be automatically performed in the indicating circuit. However, either scheme can be expected to work over a large density range only if the original integral densities are approximately monochromatic. Even then, the correction would be imperfect, although the resulting numbers might be useful in many applications. The principal reason for disregarding this possibility has been the interest in analytical density scales, which involve additional objectives in a somewhat different direction.

Before discussing these additional features, the second of our requirements must be briefly considered. Since an image on the film is uniquely specified by any three integral densities, it follows that it must be possible to infer the color of the image from the three density numbers. However, it has been the intent of our requirement that the correlation between these numbers and the color of the image should be easy to visualize and remember. This is not the case in the systems considered in the preceding paragraph. Figure 11 shows a conventional integral density plot in which narrow-band filter densi-

ties for a hypothetical print are plotted against the logarithms of camera exposure. While it is possible to guess that the highlights will be reddish, the middle densities bluish and the shadows green, it is difficult to go beyond these meager and uncertain statements. Considerable experience is necessary before density numbers can be reliably interpreted as approximate image colors. The practice of

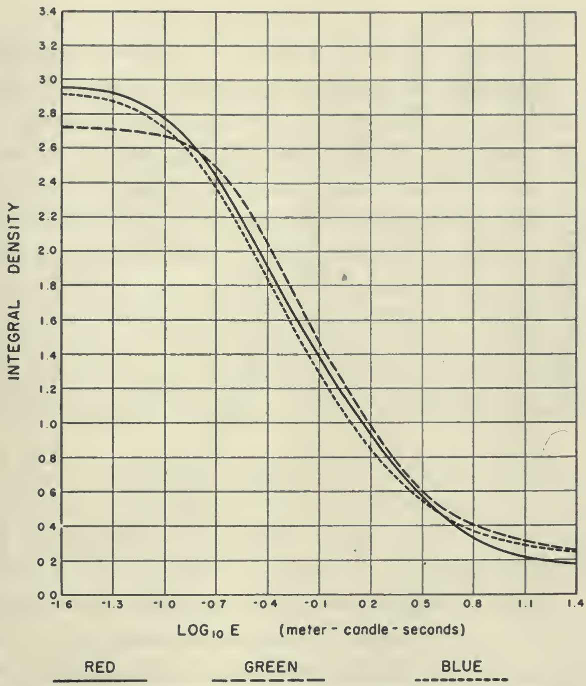

Fig. 11. Integral density plot of the over-all characteristic curves of a hypothetical process. Red, green and blue narrow-band filter densities are plotted against the logarithms of exposure. The relative positions of the curves suggest reddish highlights, bluish middle tones and green shadows.

estimating color by color density differences is fairly common, and often includes the plotting of such differences on trilinear co-ordinate graphs. The danger of this practice lies in the circumstance that the correlation between image color and density differences is different at different levels of absolute density. A given set of density differences in two images of different absolute density levels does not guarantee

that the images have the same color. Experience in the interpretation of density difference data must therefore be separately acquired for each density level.

It has been suggested that, in the absence of such experience, the relationship between image color and densitometer readings can be determined and catalogued. If this relationship does not shift with normal variations in processing or emulsion composition, it is possible

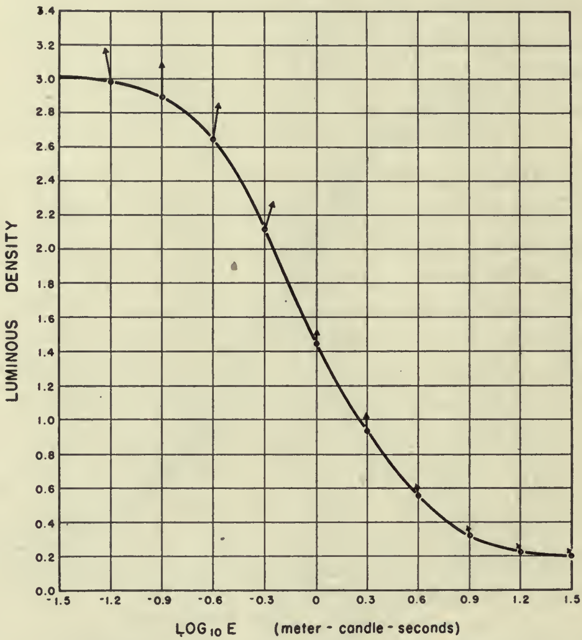

Fig. 12. Gray-scale reproduction characteristics of a color process. Luminous densities of approximately gray images are plotted against the logarithms of exposure. For each step, a small vector is shown; its direction is related to the hue, and its length to the saturation of the image. A zero vector would indicate an accurately gray image.

to construct tables or graphs by means of which a set of three integral densities may be translated into luminous density and two numbers associated with hue and saturation.

These numbers can be represented by a point on an ICI chromaticity diagram,[11] and a vector can be drawn to this point from the point which represents zero densities. A small-scale replica of this vector can then be drawn on the luminous density plot (see Fig. 12); for each

step, this small vector is drawn from the point representing that step on the H&D curve. The direction of the vector is related to the hue of the sample, the length to its saturation. Where there are available densitometers which measure colorimetric densities directly, this method of presentation is relatively straightforward. If integral spectral densitometry is used, the construction of the necessary empirically derived tables and graphs and their interpolation are relatively complex.

Analytical Color Densities

In problems connected with the manufacture and improvement of color film and color processes, it is frequently important to study images in terms of the individual amounts of the dyes. As outlined in Section IV, a description of the image in these terms is provided by analytical densities. If the scales of analytical densitometers are calibrated to yield equivalent neutral densities, or if the latter are obtained by calculation (see Section VI), one of our former requirements is automatically satisfied: Visual grays are specified by three equal density numbers. Whether the requirement for easy visualization of image color is better met by equivalent neutral densities than integral densities is controversial; neither system is very good in this respect.

The important advantage claimed for analytical densities is in a somewhat different direction. In the adjustment of the process for optimum results, it may be possible to perform changes which affect the formation of only one of the three dyes. For example, in a process involving separate color developers, the contrast of one of the dye images may be varied independently of the other two. If the magenta contrast is increased in the process illustrated in Fig. 5, the magenta curve will follow a steeper course, while the other curves will remain unchanged. This direct interaction between a variable that can be manipulated and a simple change on a sensitometric graph is of great value. Had integral densities been used in the case under discussion, the green curve would have become substantially steeper, but the blue curve would also have become somewhat steeper. With two or more simultaneous process changes of this type, the effects may be very difficult to isolate on integral density graphs.

On the other hand, the assumption of independent process variables operating on only one dye is somewhat idealized, and the usefulness of analytical densities can be more eloquently argued for a manufac-

turing establishment than a processing laboratory. For the latter, the use of equivalent neutral densities will be justified if their plot gives a clearer picture than the integral density plot of the effects of the processing variables that can be adjusted. The decision must be based on experience with a particular process. Once the choice has been made it is not easily changed, because the interpretive experience gathered by the sensitometric staff cannot be transferred.

Non-Gray Exposures

The importance of supplementing the usual gray scale sensitometry with the study of non-gray exposures has already been stressed. To determine the fidelity of reproduction of chromatic exposures (filters in the sensitometer, or test charts before the camera), visual judgments may be supplemented by colorimetric comparisons. It must be borne in mind that the accurate reproduction of highly saturated colors is beyond the capability of current three-layer subtractive processes. Standard methods for the interpretation of colored sensitometric images have not been formulated. In most laboratories, reference color densities for non-gray test patch images will be empirically established, and the actual densities obtained during process adjustment will be evaluated with respect to these reference densities.

Evaluation for Printing

In professional motion picture practice, the essential features of a camera original are contained in its printing densities. Printing densities describe how the original record of the scene will control the next step of the photographic process. This next step will be the printing either of the final positive or of an intermediate film. In either case the camera original is essentially only a means by which the point-to-point exposure made in the camera by the scene image can control the point-to-point exposures of the final positive print.

In considering evaluation for viewing, it was pointed out that "if the camera original has certain systematic defects, the print process will be adjusted, wherever possible, to compensate for them." It is equally true that whatever the systematic characteristics of the print material, the camera original or printing operation must be adjusted to best utilize them. In either event, essential knowledge can be derived from characteristic curves of the camera original material, plotted in printing densities.

A typical set of printing density curves for a color negative material has already been shown in Fig. 1. In evaluating such curves the three members of the set must be considered both individually and as a group.

The interpretation of the individual curves is but little different from the interpretation of a characteristic curve of a black-and-white negative material. Each curve represents, in fact, a negative which will control the printing of one of the components of a positive material. The "speed" of the negative can be determined by a gradient method[25] or a fixed-density method, just as in black-and-white sensitometry. Methods in use vary with the product and with the individual sensitometrist. Any method must meet two requirements:

(1) Variations from sample to sample in the "speed" thus determined should directly measure the required or permissible variations in camera exposure of the product.

(2) Disagreement among the "speed" values from the three curves of the negative material should correlate well with any changes of camera lens filter or illuminant quality required to make best normal use of the product sample. Measurements made in the toe portions of the negative curves have generally been found most satisfactory for these purposes.

The absolute density values of the individual curves are, in principle, much less important than the density relationships. The over-all density of a negative curve determines the amount of printing light required to print it; as long as the printer intensities can be made sufficiently high to permit printer operation at economical film speeds, it matters little what the absolute density levels are. Even the variations encountered (from product to product and sample to sample) in the *differences* in over-all density level of the separate printing density curves of negative materials can be offset by changes in printer setup. Of the qualities in the negative that can be shown by a gray scale test, the really important ones are those that are dependent on the curve gradients.

In black-and-white sensitometry, the most familiar expression of gradient is *gamma,* the slope of the straight-line portion of the sensitometric curve. In color photography the curves so rarely have straight-line portions that the term "gamma" is seldom used. It is replaced by average gradient, sometimes called *contrast,* although the term is rather ambiguous. *Average gradient* is measured by either of two methods: (a) by selecting a minimum and a maximum value of log E

which together define a region of particular interest, and determining the slope of the straight line joining the points on the characteristic curve corresponding to these exposures, or (b) by selecting a minimum and a maximum density which define a density region of particular interest, and determining the slope of the straight line joining the points on the characteristic curve at which these density values occur. The exposure or density intervals may be intended to encompass the entire useful exposure or density range of the negative, or more frequently only a part of it, such as the highlight, or middle-tone, or shoulder portions.

Many print materials are designed to operate best with negatives equivalent to an equal-contrast set of separation negatives. For these print materials, the color negatives are presumably best when their printing-density curves can be made congruent simply by overall density adjustment. This requires that along all possible vertical lines within the usable range of exposure, the three negative curves must show constant separation. This condition is not met by the curves of Fig. 1. Among other defects of the represented material are too low a gradient in the low-density region of the green-density curve, too low a gradient in the shoulder region of the same curve, and too high a gradient in the shoulder portion of the blue-density curve. The effects of mismatch between blue and red speeds are shown in the lack of constant separation between their toe portions. This mismatch is normally assumed to be undesirable. It is true that, particularly in professional work, no such assumption is safe, since the best characteristics of the negative are those which best fit the positive material, but it is equally true that negative-positive adjustments that compensate for each other's deficiencies in a complex manner, are useful only under uncomfortably limited conditions of exposure and processing.

Process Control

The primary task of process adjustment ends at the point where it is decided that the results will be acceptable without further modification. After this point, the manipulation of the process becomes a problem of *control,* with the objective of minimizing all departures from the reference results. Successful process control requires, first of all, that the process conditions known to produce satisfactory results are specified as completely as possible in terms of all the variables to which the picture results are sensitive. This includes the concentra-

tions of active solution constituents as well as physical parameters such as temperatures and flow rates. The identification of the critical variables is one of the major problems of process research, and much work remains to be done in this field.

While the primary method of control is continuous adjustment of these variables to the standard values, a final check is generally maintained by sensitometric procedures. Here again, the results are compared with reference values obtained under conditions known to produce satisfactory results. Such reference values are usually given as density values for definite test exposures. The choice of the particular exposures and the specification of the type of density will be governed by individual circumstances.

At first sight, the task seems very much simpler, since the objective is only to duplicate previously obtained density values. Any system of color sensitometry will serve to detect whether an earlier result is or is not repeated. In actual practice, exact repetition is only achieved in exceptional cases; usually the tests exhibit small departures from the aim. Frequently, an attempt is made to utilize measurements of this difference as indications of corrective measures. Whether this is sound procedure or not is controversial; many process operators believe that primary measurements of the process variables provide more sensitive and more reliable guidance. Where sensitometric indications are used, data should be selected that are closely related to process variables that can be manipulated. Generally, this will mean controlled exposures made directly on the print film, in place of the printer exposures made from negative images (as discussed under *Evaluation for Viewing* above). Detailed control studies are necessary to be sure whether integral or analytical densities are preferable; where the answer is uncertain, the decision will often be in favor of the method for which adequate instruments are available.

Printer Adjustment and Control

The use of sensitometry in printer adjustment and control is in many ways similar to its use in process adjustment and control. Sensitometric calibration of the available variables is equally important in the two cases, but easier in the case of printer operation than in process operation. In both cases sensitometric specification of proper conditions must be established, and in both cases departure from proper condition must be expressed in terms easily related to the calibration of the available variables.

The known methods of color sensitometry do not provide exact objective specification of the best possible printing of a color negative or positive. Picture judgments are required to specify the final printing adjustments. But sensitometry has these important functions in printer operation:

(1) Specification of printer conditions required for a given negative to a precision sufficient to provide first approximations from which further corrections can be confidently predicted by picture judgments.

(2) Specification of printer changes to minimize differences among print film stocks.

(3) Specification of printer changes to produce a known desired effect.

The efficient use of sensitometry in these functions requires establishment of correlations between printer changes and negative characteristics (assuming a negative-positive process), and between printer changes and print-image characteristics. Theory suggests that the correlations will be most direct when printing densities are used for the former, and equivalent neutral densities for the latter.

Most of the sensitometry involved in *printer adjustment* will make use of a camera-exposed image of a gray scale on the negative material to be printed. For initial adjustment, it may be assumed that this scale is to be reproduced as gray (at least in its middle tones). A trial print which is not gray can yield sensitometric information adequate for approximate correction. The separations of the equivalent neutral density curves of the reproduction define the corrections to be made in the relative exposures of the red-, green- and blue-sensitized components. They will also show what step of the negative gray scale is being reproduced at the density which is assumed correct for reproduction of white. Printing densities of the negative gray scale will reveal the differences between the densities of this step and of the step corresponding to white. The printer is to be adjusted in accordance with these differences. These adjustments, or possibly a second round of them, will set the printer well enough to make a series of trial picture prints.

When the best possible picture print has been made and chosen, a record can be made of the sensitometric characteristics of the corresponding gray scale. This correlation, corrected and extended by subsequent experience, will serve as a practical guide in making trial prints based on printing density measurements of other camera-ex-

posed negatives, representing other scenes and possibly other negative materials.

Where direct photometric measurements are unobtainable, *printer control* can be exercised by comparisons of prints resulting from printer exposures made through a standard sensitometric-scale negative with prints, simultaneously processed, resulting from sensitometer exposures; that is, the printer is controlled by reference to an unchanging sensitometer, using the print material as the comparison medium. Ideally, this comparison should be made by use of analytical densities of the resulting prints, but the comparison should be made using images so nearly identical that any three-filter densitometry should suffice.

The effects of change of print film stock can be evaluated in several ways; analytical densities, preferably equivalent neutral densities, give the information most directly related to the changes in printer adjustments which can be made to minimize the differences. The analytical density curves permit the direct determination, with reasonably good accuracy of the required changes in the individual layer exposures. If the printer adjustments cannot change these exposures individually, it is possible to set up a quantitative calibration by a procedure similar to the transformation of integral to analytical densities.

Sound Track Evaluation

The evaluation of sensitometric tests for sound records on color film follows the same principles that have been considered for picture records, although the actual procedures are different. The quality judgments that are obtained for the picture area by screen viewing and by colorimetric measurements have their sound track counterparts in listening tests and in electrical measurements.[26] The adjustment of sound track printing and processing is governed by tests of sound quality (e.g., measurements of signal-to-noise ratio and intermodulation tests). Until the conditions for optimum reproduction have been established, sensitometric procedures are restricted to a secondary role. Once the optimum conditions are known, they can be correlated with sensitometric measurements which may then become the primary means of control. At that stage, the problem of interpretation becomes one of comparing the sensitometric characteristics of a given test with reference data.

The density values used for such comparisons must correspond to the action of the sound track image in the sound reproducer. An integral density measured in a narrow region of the visible spectrum may be a completely misleading indication of image performance in a sound system using customary photocells with cesium oxide or S-1 surfaces. The maximum sensitivity of these photocells lies in the infrared region near 800 mμ, where most dye images are quite transparent. A quite different spectral sensitivity with a maximum near 400 mμ is obtained in photocells with S-4 surfaces; such cells have been successfully used[27] in experiments with dye sound tracks. In the 16-mm field, lead sulfide cells[28] with maximum sensitivities in the range from 1000 to 3000 mμ have recently come into some use. The SMPE Color Committee voted in October, 1949, to ask the color film manufacturers to determine which of these phototubes are best suited for reproducing sound recorded on their particular color products. Meanwhile, the interpretation of sound track sensitometric tests should be based on integral densities that accurately represent the spectral response characteristics of the particular type of sound reproducer with which the film is to be used. This will normally require a densitometer equipped with a photocell of the same type as that used in the reproducer.

VIII. STATISTICAL ASPECTS OF COLOR SENSITOMETRY

The nature of sensitometric measurements and the materials on which they are made give rise to random variations in the results. In the presence of these random variations precise determinations are not possible on the basis of a single experiment. Reliable conclusions can be drawn, however, from multiple experiments interpreted by statistical methods. Experienced operators have long realized the distinction between significant and insignificant differences in results, but the quantitative study of these variations and of their bearing on control problems is a relatively recent development. Within the limits of the present report, these methods cannot be fully described nor even adequately outlined; the purpose of this final section is simply to call attention to the existence of this new and important phase of color sensitometry.

Statistical Variation of Results

When several duplicate exposures are made on a small sample of photographic material, and the group is processed together under carefully controlled conditions, and then measured on a correctly adjusted densitometer, the individual images will not have identical densities. If the sensitometric test procedure is well controlled, these density variations will represent random variations for which no specific causes can be assigned.

Variations greater than these random variations, for which assignable causes can be found, will often be observed when (a) different coatings of photographic material are tested, (b) the material is exposed on different sensitometers or on the same sensitometer at different times, (c) the strips are processed at different times, and (d) the processed strips are read on different densitometers or on the same densitometer at different times. An important problem of color sensitometry is the evaluation of such systematic differences from data which contain the random variations.

Individual Sources of Variation

Among these different components of systematic variability the only one that can be isolated for independent study is the densitometric variation. Its magnitude can be determined by measuring the same processed sensitometric strip on several densitometers, or on the same densitometer at various times. An objective of good densitometer design and of sound maintenance and control procedures is the

reduction of this particular source of variation to the minimum value that is economically practical.

Variations in sensitometric exposure cannot be isolated on finished sensitometric strips, but photometric methods can be used to arrive at an independent check on the magnitude of such variations.

On the other hand, there is no completely satisfactory procedure by which variations in film or processing can be independently studied. The difficulties of separating these two factors have already been considered in Section III. The best that can be done is to study one of the components of variation under conditions that make the remaining components relatively small. For example, a single test of film variability can be made by exposing sensitometric strips as closely as possible at the same time on a carefully controlled sensitometer, and then processing all of the strips in random sequence at the same time. Where repeated tests of this kind are required, it will be desirable to keep process variations small, because differences in film characteristics vary with process changes.

Multiple Factor Experiments

Statistical methods[29] are available for the treatment of more complicated experiments in which two or more factors are separated and evaluated in the same group of experiments. However, in applying such methods to problems involving film and processing variations, one must be sure to exclude assignable causes of variation resulting from "keeping" changes in the film during the intervals between manufacture and exposure and between exposure and processing. This is very difficult in practice, and multiple factor experiments have therefore been little used in color sensitometry.

As an illustration of a somewhat different use of such multiple factor experiments, consider the problem of maintaining two or more densitometers so that six different test operators will be able to obtain essentially the same densitometric measurements on all parts of the scale of a sensitometric strip. Each test operator would be asked to make density measurements on several sensitometric strips using both densitometers. The resulting data could be studied by variance analysis[29] to see whether significant differences existed between the results from Operator A and Operator D, or between Densitometer No. 1 and Densitometer No. 2.

Statistical Methods of Data Presentation

Statistical methods are most efficient when used to help interpret the results of experiments which have been properly designed. Several

simple statistical methods can be used to present data and interpret experimental results in color sensitometry. It should be emphasized that no method of summarizing and presenting experimental data should ever lead the reader to draw different inferences than he would have drawn (more laboriously) by references to the original test results.

Frequency Diagrams

Frequency diagrams[30] (histograms) can be recommended for studying the results of large experiments when the order in which the ex-

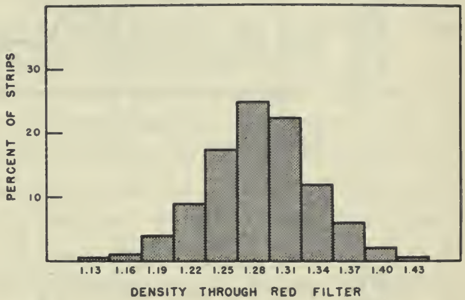

Fig. 13. Frequency diagram (histogram) for the red densities of 462 images obtained during an arbitrary test run.

Table III. Densities Through Red Filters During an Arbitrary Test Run

Densities	Number of strips	Percentage of strips	Densities	Number of strips	Percentage of strips
1.12 to 1.14	2	0.4	1.30 to 1.32	104	22.5
1.15 to 1.17	5	1.1	1.33 to 1.35	55	11.9
1.18 to 1.20	18	3.9	1.36 to 1.38	28	6.1
1.21 to 1.23	41	8.9	1.39 to 1.41	9	1.9
1.24 to 1.26	81	17.5	1.42 to 1.44	3	0.6
1.27 to 1.29	116	25.1			
			Total	462	99.9

perimental work was done is not of great importance. They are usually preferable to tables because they immediately convey a graphic picture. Figure 13 shows a frequency diagram for the sensitometric tests made on samples of film made during an arbitrary test run. The information shown in this graph is equivalent to that contained in Table III. The shape of such histograms gives important information about how well the process was controlled during the period under study. Well controlled systems usually produce single-

peaked distributions which are symmetrical. A narrow tall distribution indicates a more uniform product than a wide shallow distribution.

Control Charts

The order or time sequence in which a set of experimental results was obtained can be shown by presenting data in the form of a con-

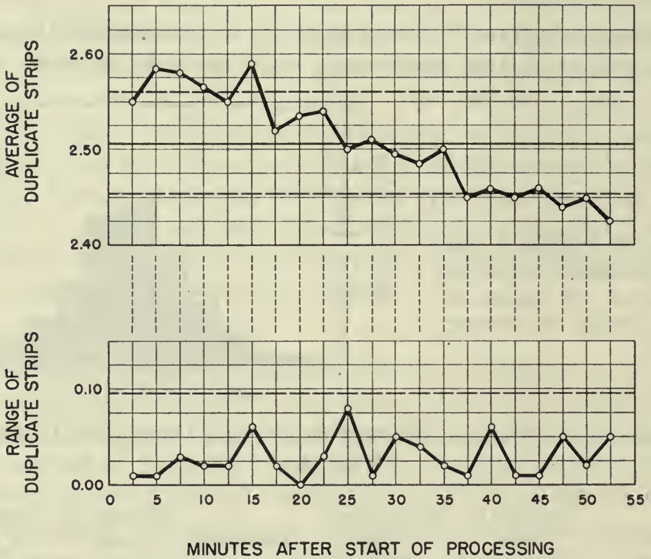

Fig. 14. Statistical control chart for a one-hour run of an experimental process. Duplicate strips were run at 2½-min intervals, and the blue densities were read for one image on each strip. The lower chart shows the density differences between duplicate strips. The upper chart shows the average density of duplicate strips. The downward trend shown on the upper graph exceeds the control limits calculated from the results shown in the lower graph.

trol chart.[30] The experimental work should be designed so that the results can be arranged logically into rational subgroups. These rational subgroups can be chosen within test machines, within test operators, within arbitrary units of material, within stated periods of time, and in many other logical ways. The control chart compares the variability of the entire set of results with the variability within these rational subgroups.

Figure 14 shows a control chart for the results of processing dup-

licate sensitometric strips at $2\frac{1}{2}$-min intervals for about one hour in a single processing machine. The present illustration is concerned only with the blue integral densities of one specific step on each strip. The rational subgroups, in this experiment, are the groups consisting of the two strips processed at the same time. The density difference between two such strips (the "range" of duplicate strips) is taken as a measure of the variability within each subgroup. The lower graph in Fig. 14 shows this quantity for each of the 21 subgroups. The dotted line on this lower graph indicates a statistical control limit based on the average range. Within the duration of this experiment, all ranges of duplicate strips are within the control limit; this is interpreted to mean that differences observed between duplicate strips processed together are due to nonassignable chance causes.

This minimum random variation also provides a basis for calculating the control limits shown by dotted lines in the upper graph of Fig. 14. Here, average densities of each set of two strips are plotted. As long as these average densities are within the control limits, the variations observed in the result may be considered as random effects from unassignable causes. The upper graph shows, however, that in the test under discussion the variations extend beyond the control limits. This is interpreted to mean that the downward trend shown during the hour may have had non-random origin. Such a situation would justify a careful search for specific causes of trouble.

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New 13.6-Mm Hitex Super High-Intensity Carbon

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Summary—**The new 13.6-mm Hitex super high-intensity carbon for operation at 170 to 180 amp in condenser-type lamps is described in comparison with the former 170-amp super. Data show that the Hitex super carbon gives the possibility of more light, more economical operation because of longer life and a marked improvement in efficiency of light production. Spectral energy and color data show that the light from the Hitex super has a higher color temperature than from the old super.**

The task of providing adequate illumination on the largest screens used for the projection of motion pictures is one which has presented a continual challenge to the manufacturers of the equipment involved. Many large indoor theaters have never had as much light as was needed to obtain the results desired. The problem has been intensified in more recent years with the advent of many large-screen outdoor theaters which have much less light available on the screen than necessary to bring them up to the desired levels of screen brightness. The use of audience viewing areas several times larger than indoor theaters has necessitated the use of considerably larger screens. Projection screen areas are approximately four times as great for outdoor as for indoor theaters and consequently require four times as much light to achieve the same screen brightness. It cannot be definitely stated that outdoor theaters, with their different circumstances and surroundings, should have the same brightness as indoor theaters; but there is no doubt that most of them could effectively utilize much more light.

The condenser type of lamp employing rotating positive high-intensity and super high-intensity carbons is widely used by large screen theaters. The first step in the field of super high-intensity projection for large theaters came in 1936 when the 13.6-mm National super high-intensity carbon was introduced.[1] This carbon was designed for operation at 180 amp and produced more light more evenly distributed on the screen than carbons previously available. Further

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attention to the problem made it possible to introduce an improved 13.6-mm super carbon in 1941 for operation at 170 amp.[2] This carbon gave a 20% increase in light over the 1936 super with a 10-amp reduction in current and no increase in burning rate.

Continuing research and development work since 1941 has resulted in new methods of processing which make possible improved carbon compositions and properties. As a result, the new National Hitex super carbon has been introduced and reached new highs in the field of super high-intensity projection. It has brought greatly improved efficiency of light production and lower cost operation along with an increase in screen brightness.

OPERATING CHARACTERISTICS AND PERFORMANCE

The new Hitex super carbon is rated at 170 to 180 amp and has the burning characteristics shown in Table I. The light output on any

Table I. Characteristics of 13.6-Mm Old and New National Super High-Intensity Projector Carbons Under Typical Operating Conditions

	Old super	New Hitex super	
Arc amperes	170	170	180
Arc volts	75	70	74
Positive consumption rate (inches per hour)	24.0	16.0	21.5
Screens lumens at maximum light*	21,500	20,700	24,800
Side-to-center screen distribution ratio at maximum light	65	60	60
Screen lumens at 80% screen distribution†	18,500	17,500	19,300

*Screen lumens with no projector shutter, film or filters; condensers at $f/2.0$ adjusted for maximum light.

†Same as screen lumens at maximum light, except that condensers are adjusted for 80% side-to-center screen ratio.

given projection screen with these carbons will depend on a number of different factors. The influence of these various factors and the results obtained with typical projection systems were discussed in a recent paper.[3] Light measurements given in Table I have been made with the Hitex carbons on a typical condenser system in comparison with data previously obtained and published for the 13.6-mm super carbons[3] along with a description of the conditions under which they were obtained. With the optical system adjusted to produce maximum light on the projection screen, the Hitex super, at the lower end of its current range, approximately equals the light output of the old

super; and, at the upper end of its current range, it gives approximately 15% more measured light than the old super. At 80% side-to-center distribution ratio on the screen, the amount of light with the old super is intermediate between the values obtained from the Hitex super carbon at its two extremes of operating current. The Hitex super carbon, therefore, gives a certain flexibility, making possible, as it does, a range of light output running from a value at minimum operating current just below that of the old super upwards to one substantially higher at maximum operating current.

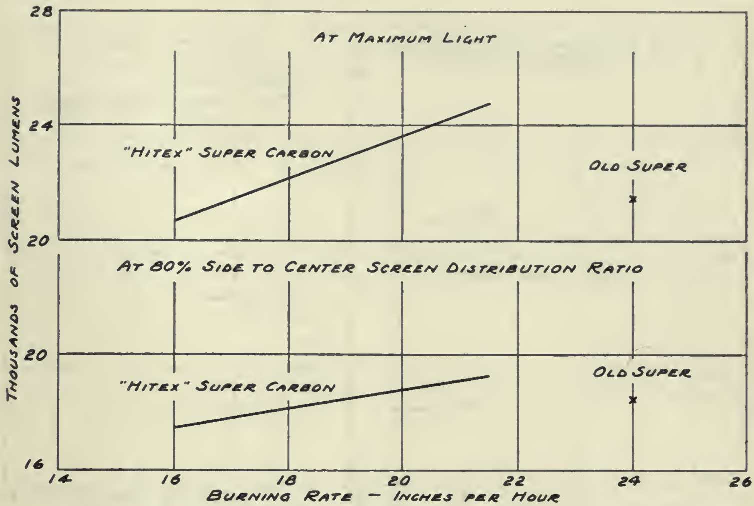

Fig. 1. Screen light with 13.6-mm super high-intensity carbons vs. burning rate, no film or shutter.

Figure 1 shows the data of Table I with the screen light plotted against the burning rate in inches per hour. Since carbon cost per hour depends on the burning rate, this method of plotting shows the amount of light at the various consumption rates and correspondingly different values of carbon cost per hour. Although the two carbons cover different burning rate ranges, it can be seen that the Hitex super carbon produces light much more economically than the old super. For example, at equal light output, the Hitex super carbon has about 30% to 40% longer life. The new carbon at 170 amp will project three double reels of 35-mm film per carbon compared to two double reels for the old super and therefore gives 50% longer burning life at

this current. At 180 amp, the Hitex super carbon will project two twenty minute reels and an additional short reel.

As is indicated by Table I and Fig. 1, higher light with a given optical setup is always accompanied by a higher carbon burning rate. The light output of a given carbon divided by its burning rate gives a measure of the total amount of light energy produced per inch of carbon consumed and measures the efficiency of conversion of the carbon into light energy. This efficiency is expressed in lumen-hours per inch and is plotted in Fig. 2 against the corresponding value of screen

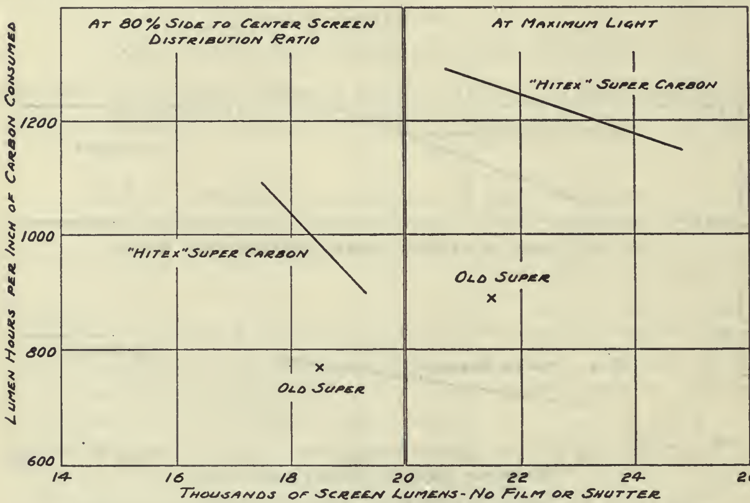

Fig. 2. Efficiency of conversion of carbon into light energy vs. amount of light produced.

lumens produced. This shows first that there is some decrease in efficiency upon going to the higher currents and higher amounts of light with a given carbon. Secondly, at corresponding amounts of light the Hitex super carbon has from 30% to almost 50% higher efficiency than the old super. Even at its highest current, where it produces more light than the old super, the Hitex still has approximately 15% to 30% higher efficiency.

The total amount of electric power consumed from the line will be proportional to the arc current with either a local, constant voltage d-c generator or a utility d-c power supply line; therefore, the amount

of light divided by the arc current, that is the lumens per ampere, is a figure which measures the efficiency of conversion of electric power into light. This measure of efficiency is plotted in Fig. 3 against the corresponding amount of screen light produced. This shows, first, that the efficiency of conversion of electric power into light increases as the current and the amount of light are increased. Secondly, Fig. 3 also shows that the Hitex super carbon has essentially the same power efficiency as the old super at corresponding amounts of light. This means that the advantages of the Hitex super carbon, such as its higher light, longer life and its greater efficiency of conversion of carbon into light energy, have all been achieved without any sacrifice of efficiency of utilization of power.

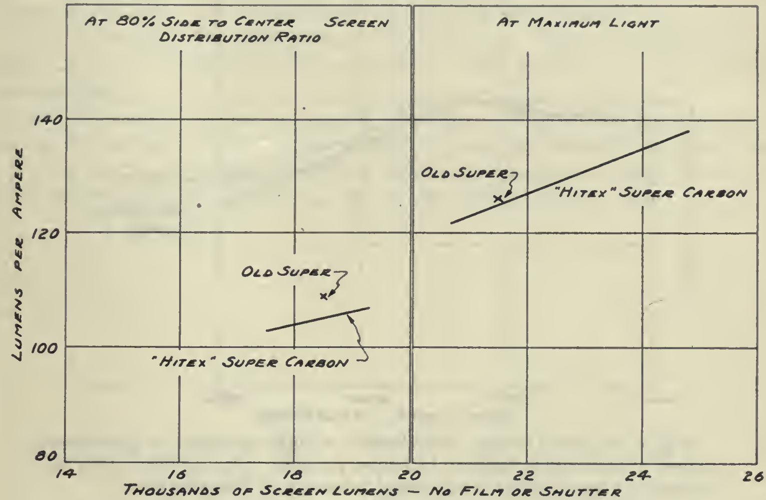

Fig. 3. Efficiency of conversion of electric power into light vs. amount of light produced.

The light on the projection screen with the Hitex super carbon has a higher color temperature than with the old super. Comparison with the light from the old super on a blank screen without any film being projected, results in the appearance of a whiter light with the Hitex carbon. A spectral energy distribution curve of the light at maximum on the screen is given in Fig. 4 for the two carbons at 170 amp. The corresponding color temperatures are 5925 K (degrees Kelvin) for the old super and 6250 K for the Hitex super carbon.

Detailed measurements of total radiant energy falling on the film aperture have not yet been made with the Hitex super carbon by the method used in previous publications.[4] However, comparative measurements made with a new type of aperture heat meter recently described[5] have shown that the Hitex super carbon gives more measured light per unit of heat at the aperture than does the old super carbon. The difference amounts to approximately 15%. As a matter of fact, the Hitex super at 180 amp does not give measurably more total energy at the aperture than does the old super at 170 amp in spite of the 15% advantage in light. It would be expected that this

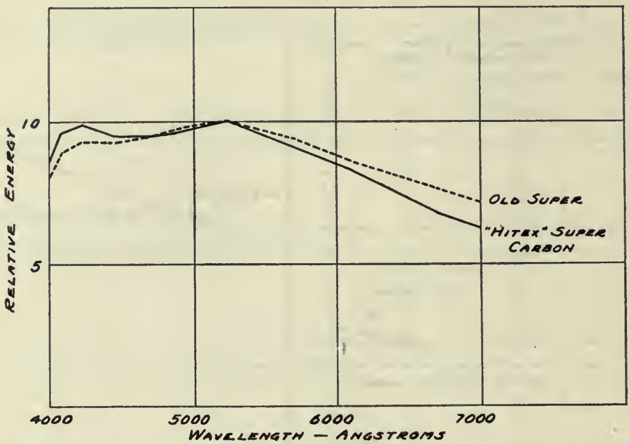

Fig. 4. Spectral energy distribution of light at center of projection screen at maximum light at 170 amp, no film. Curves have been adjusted to approximate same visual intensity of illumination.

magnitude of light increase can, therefore, be obtained with the new carbon without any increase in severity of the heat-on-film problem.

The ½-in. National Heavy Duty Orotip negative carbon is recommended for use with the Hitex super carbon over its entire current range.

The former 13.6-mm super carbons operated best with the axis of the negative carbon intersecting the positive crater face intermediate between the center and the lower lip of the crater in order to obtain an optimum combination of stability, light output and burning rate. The optimum position with the Hitex super occurs with the negative axis shifted a little lower so that it intersects the crater face approximately at the lower lip.

Summarizing, the Hitex super carbon makes it possible to project more light on the projection screen that could previously be done and at the same time this is accomplished with a worth-while reduction in cost of operation resulting from improvements in the efficiency of utilization of carbon and of electric power.

NOTE: The terms Hitex, National and Orotip are registered trade-marks of the National Carbon Div., Union Carbide and Carbon Corp.

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Television Recording Camera Intermittent

By JOHN M. WALL

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Summary—This is a brief description of the Wall 16-Mm Camera Intermittent that lends itself easily to meet the demands for fast film pull-down in television recording cameras. Pull-down time has been cut to .005 sec.

The advent of television broadcasting brought new functional requirements for motion picture cameras. Probably the most outstanding of these problems was the intermittent, for this truly is the heart of the camera.

It seems that in order to synchronize the difference in frame frequencies between television, having 30 frames/sec and the standard motion picture camera with 24 frames/sec, it is necessary to have not more than 72° of shutter or film pull-down time in the motion picture camera. It is also necessary to make allowances for losses in the shutter timing devices due to various electrical and mechanical functional tolerances.

All factors combined, it is therefore necessary in some extreme cases to limit the film pull-down time to 40°, or one-ninth of a cycle.

In analyzing this 40° pull-down time, it will be found that 40° is one-ninth of a picture cycle, which, at the rate of 24 picture cycles/sec, gives the actual time for pulling the film from one frame to the next as a little less than .005 sec.

Although the length or mass of film moved by the intermittent is approximately 10 in. in length and consequently has very little weight, still, in the case of the 16-mm film which has sprocket perforations on only one edge, there is some danger of tearing the film at the sprocket perforations if the film is started too quickly.

This intermittent reduces such possibilities to the minimum because of its slow starting and stopping.

This intermittent lends itself very nicely to changes in film pull-down time, for although the Wall Standard 35-mm intermittent has a film pull-down time of 157°, this can be greatly reduced in either the

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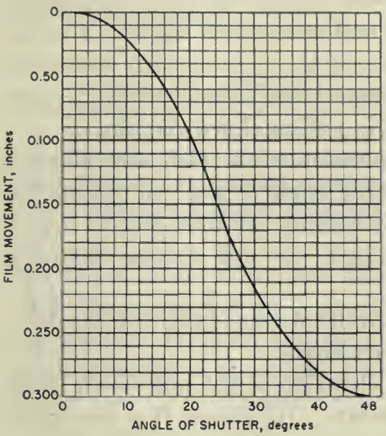
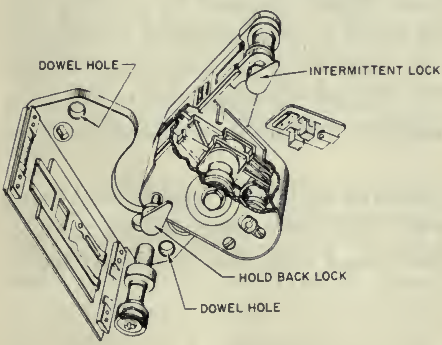
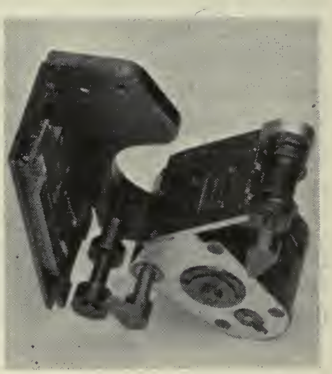
35-mm or the 16-mm intermittents by simply changing the working angle of the cams.

The reduction of the pull-down time was no new problem as patents were already secured covering fast pull-down on the 35-mm intermittent, so it merely became a problem of applying the earlier work to the 16-mm intermittent.



Lineal movement of film in .001 in. per degree of angular rotation of shutter during intermittent pull-down cycle.





Wall 16-Mm Camera Intermittent.

One of the unique features of this intermittent is that the cams have two dwell and two working periods in each cam cycle. Also, the cam follower has two parallel surfaces that are at all times in contact with opposite sides of the cams; thus the cam in reality is both active and complementary in its performance.

In designing the 16-mm intermittent, we therefore decided to use the same construction that has proven so satisfactory in the 35-mm intermittent. Thus, by reducing the working angle of the cams to the minimum angle permissible, we were able to reduce the pull-down angle to 81°58′5″ but this was still 41°58′5″ greater than the minimum of 40°.

In the Wall Intermittent, the pull-down lever has its fulcrum point at one end and the pin that engages and pulls down the film is in the other end and at some point in between is located the cam; therefore, the effective angle of rotation of the cam is the normal working angle plus the angle which the lever forms in pulling down the film.

So, by changing the direction of rotation of the cam, the effective angle of rotating would be the working angle of the cam minus the angle of the pull-down lever. In this manner, we were able to reduce the pull-down angle to 65°54′15″ which was still greater than the minimum of 40°.

By offsetting the center of the intermittent cam shaft with the drive shaft, we were able to gain the necessary angle.

Due to rapid acceleration and deceleration of the pull-down lever, the intermittent was at first quite noisy. We found that the intermittent moved slightly on the gibs holding it in place. This movement was eliminated and the noise greatly reduced by putting into the camera case hardened dowels which fit into hardened bushings in the intermittent frame. Also, by employing an interrupted thread type of fastening device, we have reduced the noise level to the point where on a 60° pull-down intermittent it is almost impossible to hear the intermittent run.

In tests conducted by us in cameras without a shutter and using positive stock in either a 40° or 60° pull-down intermittent, the pictures were steady, without a ghost, and with clearly defined frame lines.

Motion Picture Color Photography of Color Television Images

By W. R. FRASER and G. J. BADGLEY

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Summary—**By combining the techniques and equipment required for motion picture recording of radar PPI (Plan Position Indicator) scopes and television kinescopes, acceptable 24-frames/sec color motion pictures have, for the first time, been obtained from color television kinescopes. This has been accomplished by suitably modifying a professional type 16-mm motion picture camera and adding a specially designed high-speed 25-mm $f/0.7$ lens.**

While it is true that World War II temporarily interrupted the progress of commercial television, it is also true that numerous wartime research and developmental projects contributed in no small measure to the rapid development of television as we know it today.

The growth of television since 1946 has been truly phenomenal, especially in the larger metropolitan areas of New York, Philadelphia, Chicago and Los Angeles. The requirement to record television programs, which includes both the audio and visual record, immediately presented itself. Special cameras[1] and techniques[2,3] were developed for the purpose of furnishing documentary films and films for network syndication.

The military applications of television are numerous. The early "block"[4] and "ring"[5] television equipments were developed during World War II for air-borne reconnaissance. "Stratovision" broadcasts in 1948 and 1949 vividly demonstrated the possibilities of air-borne television to the American public. As in the case of commercial television, a documentary record of the "telecast" sometimes is mandatory and in many instances proves invaluable.

The improvement of modern color films during recent years has been a boon not only to the motion picture industry and the U.S. amateur photographer, but to science as well. Medical photography, to cite one instance, becomes many times more effective and valuable when viewed in color. The study of rocket fuels and their combustion

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characteristics is also facilitated by color photography. It is reasonable to predict that a similar revolution will occur when color television is given the green light by the Federal Communications Commission. The existing requirement to record black-and-white telecasts will, without doubt, be extended to cover a color recording of a color program from the color television screen. A whole new field of problems peculiar to color photography, including color temperature and color balance, in addition to gamma and density, will rise to complicate the job of the color cinephotographer.

Motion Picture Recording of Radar Scopes

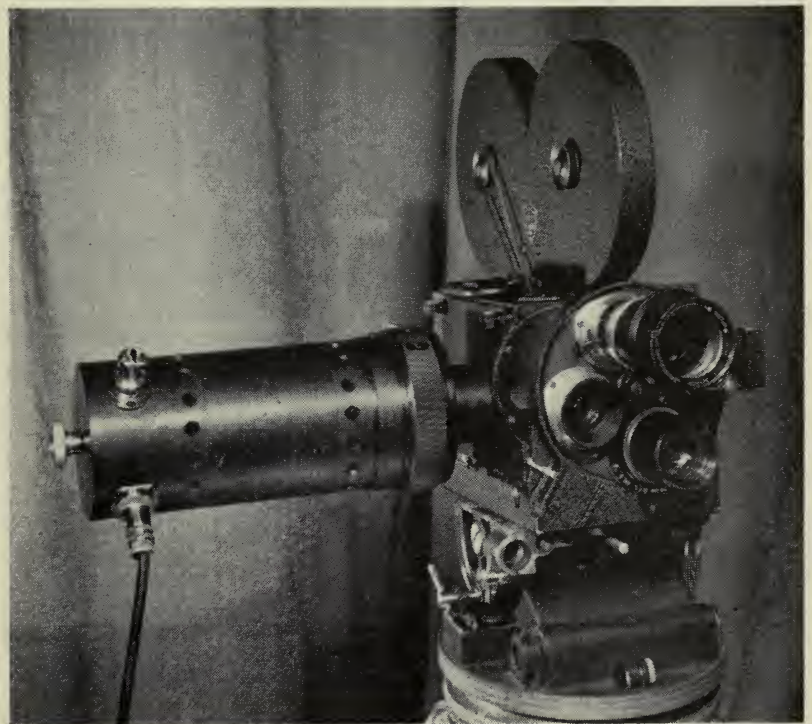
During the War, David Gray of the Polaroid Corp.[6,7] developed a special 25-mm focal length lens with an aperture of $f/0.7$. This lens was mounted on a Cine Special 16-mm motion picture camera and successful motion pictures of the PPI (Plan Position Indicator) type of radar scope images were obtained. This equipment was rotated among several agencies including the Naval Research Laboratory, Naval Photographic Center and the Massachusetts Institute of Technology. However, this arrangement was not too satisfactory, and in 1948 the Naval Photographic Center contracted with the Polaroid Corp. to build a new and improved 25-mm $f/0.7$ lens. In the design of this lens, high speed was the guiding requirement and, consequently, other aberrations including "barrel distortion" were tolerated. In spite of this, a resolution of 20 lines/mm on the axis was achieved which is quite adequate for recording PPI type of radar targets.

High speed lenses, as a general rule, have a shallow depth of field and a short back-focus distance. Before the $f/0.7$ lens could be mounted on a Mitchell 16 motion picture camera, it was first necessary to mill out a ⅛-in. deep circular section around the camera aperture to permit focusing the lens. Fortunately, in radar recording, the object distances are usually 12 to 18 in., which permits focusing in the "racked out" lens position. A new lens turret to hold the $f/0.7$ lens and three other conventional lenses completed the interim model radar motion picture recording camera (Fig. 1). Successful exposures have been secured of PPI radar scope images or targets at 24 frames/-sec with a "G" filter using this modified camera. A new radar recording camera, designed and now being built by G. J. Badgley, will have a shutter opening in excess of 310° which will increase the exposure time by approximately 80%.

BLACK-AND-WHITE TELEVISION RECORDING

The first black-and-white television recordings secured by the U.S. Naval Photographic Center were made on March 21, 1946, at the Naval Air Station, Anacostia, D.C., during the public demonstration of the Navy "block" and "ring" air-borne television equipment.

NOTE: "Block" equipment operates at a frequency of 40 fields/sec non-interlaced, while "ring" equipment operates at 40 fields/sec interlaced.



Official U.S. Navy Photograph

Fig. 1. Specially modified Mitchell 16 motion picture camera with 25-mm $f/0.7$ lens and variable synchronous motor.

Subsequent recordings with conventional lenses were made at 20 frames/sec using a Berndt-Maurer 16-mm camera with a fixed 180° open shutter.

Recording would be greatly facilitated if commercial television

were operated at 96 fields/sec interlaced instead of at 60. Such a frequency would permit recording at 24 frames/sec with a simple 180° open shutter instead of a special camera equipped with a 288° open shutter as is required by the present 60-fields/sec system. However, 15-frames/sec recordings of commercial telecasts have been made with the 180° open shutter Berndt-Maurer Camera.

A number of special recordings including underwater television and "Stratovision" telecasts were also made at 15 frames/sec (synchronous speed). During the past several years, the Naval Photographic Center has been quite active in cinephotography and, in addition, close liaison has been maintained with industry.

Color Recording of CBS Color Television

On August 18, 1949, CBS (Columbia Broadcasting System), under the sponsorship of the Smith, Kline and French Laboratories, put on the first experimental color television broadcast in Washington, D.C., for the Federal Communications Commission and other government officials. The program originated at Johns Hopkins Hospital, Baltimore, Md., and was telecast to Washington over the facilities of WMAR-TV, Baltimore, and WMAL-TV, Washington. Two receivers were installed at the District of Columbia National Guard Armory and permission was secured to set up our Berndt-Maurer camera for a few minutes in front of one of the color receivers. A 25-mm *f*/1.4 Cine Ektar Lens and daylight type Kodachrome were used. Exposures were made at 15 frames/sec synchronous, and at approximately 8 and 4 frames/sec using the hand crank. The results were quite promising in that the exposure at both 4 and 8 frames/sec was adequate.

NOTE: A portion of this footage was shown in the Navy Film on High Speed Photography during the October, 1949 Hollywood Convention of the Society of Motion Picture Engineers.

During September, 1949, hearings were convened in Washington, D.C., by the Federal Communications Commission on the subject of color television, and comparative tests of RCA, CBS and Color Television, Inc., color systems were scheduled in Washington, D.C., for October, 1949. Technicians at the Naval Research Laboratory had modified a black-and-white television receiver for CBS color, so the opportunity to try another color recording became available. Our previous exposure data indicated that by using the radar recording

camera equipped with a single-phase synchronous motor, and a 180° open shutter, the possibility of getting adequate exposure at 24 frames/sec was within reach. A series of tests with the $f/0.7$ lens mounted on the Mitchell 16 was necessary in order to reduce the "shutter bar" to a minimum. (When conventional lenses are stopped down, the shutter bar, if present, becomes more sharply defined.) It was finally determined, by cut and try methods, that a shutter opening of approximately 179½° produced a barely visible shutter bar on the film at 15 frames/sec when the conventional lenses were stopped down to $f/11$. When the lenses were wide open, the shutter bar practically disappeared. Actually, no shutter bar was apparent when the shutter opening of 177° was tried with the $f/0.7$ lens on the camera. An in-

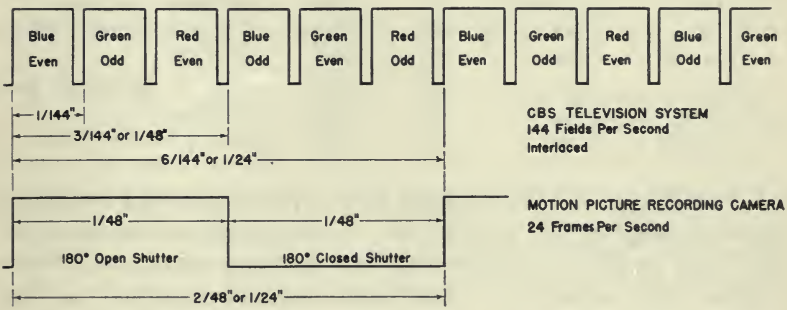


Fig. 2. CBS color television recording system.

duction motor was converted to a synchronous motor and a reduction gear box of 1,800 to 1,440 rpm constructed.

The Naval Research Laboratory receiver, as it turned out, did not have sufficient light output for 24-frames/sec recording with the $f/0.7$ lens. Both Kodak Type A and Ansco Tungsten color films were used. In order to get greater effective emulsion speed, the Ansco film was given twice the normal time of development in the first developer. Adequate facilities were not readily available for special developments, and consequently only 100 ft of film was given this type of processing. This treatment did produce a better film record, but the additional work involved was not worth the effort. The Ansco Company specially developed some Ansco Tungsten color film, but the effective emulsion speed was still not adequate. It was then considered that the work involved by special color processing

could not be justified and it was decided to concentrate on standard color development.

A special Navy Type C 16-mm camera equipped with the $f/1.4$ Cine Ektar Lens, a 4- and 8-frames/sec gear box and synchronous motor were also tried with limited success. This camera is a modified Cine Kodak magazine type equipped with elliptical gears designed to increase the exposure time per frame. Good color recordings were obtained at 8 frames/sec with this camera.

The CBS "Field Sequential" color system lends itself particularly well to color cinematography. The sequence of scanning is as follows:

Color Frame	*Time*	*Scan No.*	*Color*	
1 { 3/144 or 1/48 sec	1/144 sec	1	Blue	odd lines
	1/144	2	Green	even or interlaced lines
	1/144	3	Red	odd lines
2 { 3/144 or 1/48 sec	1/144	4	Blue	even or interlaced lines
	1/144	5	Green	odd lines
	1/144	6	Red	even or interlaced lines

A combination of 1 blue, 1 green and 1 red scan in 3/144 or 1/48 sec makes up one complete color frame. A motion picture camera operated at 24 frames/sec synchronous will therefore record every other complete color frame when a 180° open shutter is employed (see Fig. 2). Double and other even multiple exposures are possible in accordance with the following table:

Camera speed, frames/sec		*Color TV frames recorded per film frame*	
	24		1
	12		2
	6		4
	3		8
	1½		16

For the purpose of conducting exposure tests, a variable synchronous motor with the above speed markings would be ideal. Fortunately, the Producers Service Co., Burbank, Calif., recently announced a 1/15-hp synchronous motor with a built-in variable speed transmission that includes the aforementioned synchronous speeds (Fig. 1).

The American Medical Association Convention held in the Washington, D.C., National Guard Armory, December 5 to 9, 1949, presented a rare opportunity to record color television. Under the sponsorship of the Smith, Kline and French Laboratories, surgical opera-

tions performed at the Johns Hopkins Hospital in Baltimore, Md., were broadcast by microwave relay to the American Medical Association Convention. Arrangements were made to record, and on December 8 (the next to last day) it was discovered that CBS was operating at a picture frequency of 150 fields/sec instead of the usual 144 fields. This "slight" change made our 24-frames/sec color television recording camera useless. Fortunately, by working until after midnight, a new 25-frames/sec gear box was designed and manufactured.

On the morning of December 9, 1949, the first completely successful color recordings were made from the CBS Color Television receiver at the rather unorthodox speed of 25 frames/sec. Portions of two surgical operations were recorded: Resection of Colon, by Harvey B. Stone, M.D.; and Total Hysterectomy, by Richard W. Lelinde, M.D.

The following 16-mm color film, totaling 1300 ft, was exposed: two 400-ft rolls of Type A Kodachrome; one 400-ft roll of Ansco Tungsten and one 100-ft roll of Commercial Kodachrome.

As the color temperature of the CBS television tube was approximately 3800–4000 K (degrees Kelvin), C–¼ and C–⅛ Harrison color filters were used to reduce the color temperature of the television to match more closely the color temperature of the film. The quality of the color prints compared favorably with results usually obtained by direct 16-mm color cinephotography. As usual, however, there was a definite division of opinion concerning the relative merits of Kodachrome and Ansco Tungsten color films.

Subsequent recordings were made at 24 frames/sec from the CBS color monitor in Washington, D.C., during January, 1950. The best results, however, were obtained from the Smith, Kline and French receivers, which appear to have a greater tube light output. Portions of these recordings, in addition to the Corneal Transplant Operation recording, were demonstrated by CBS before the Federal Communications Commission in Washington on March 24, 1950.

The Atlanta Graduate Assembly of the Fulton County Medical Society under the sponsorship of the Smith, Kline and French Laboratories presented a three-day program of color television of surgical operations and clinics on February 6, 7 and 8, 1950, in Atlanta, Ga. This time, however, the program was telecast at 144 color fields/sec which permitted 24-frames/sec color cinephotography. Philip Bang, who was one of the early pioneers of sound recording in the South, made sound recordings of the telecast with a synchronous-driven

Fairchild 16 disc recorder. This occasion marked the first time that a color recording was made of a color telecast with the accompanying sound. Color composite prints were made and among them was the spectacular corneal transplant operation that has received nationwide publicity during the past several months.

Color Recording of RCA Color Television

Arrangements were made in October, 1949, to attempt a recording of the RCA "dot sequential" color television system and after several unavoidable delays, the first color recording was made at the RCA Silver Spring Laboratory on March 10, 1950. This initial recording was made at 15 frames/sec with a 180° open shutter, the exposure time being $\frac{1}{30}$ sec. Referring to Fig. 3, it is evident that the same ex-

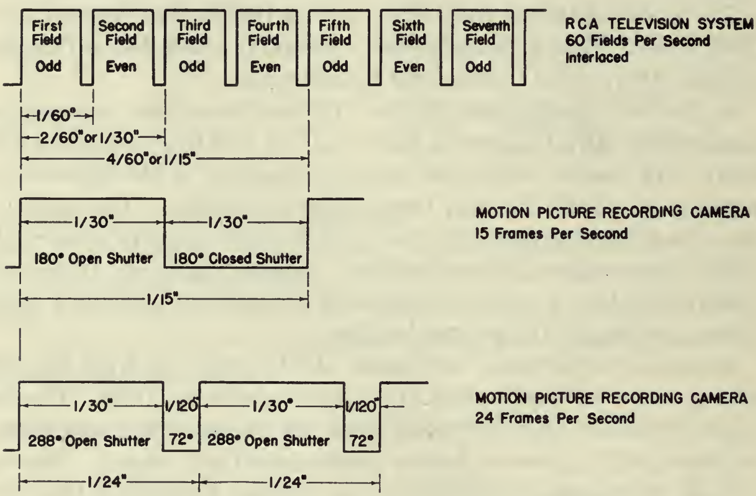


Fig. 3. RCA color television recording system.

posure time of $\frac{1}{30}$ sec is obtained at both 15 frames/sec with a 180° open shutter and at 24 frames/sec with a 288° open shutter. Completion of the new "Badgley" camera equipped with a 288° open shutter and the *f*/0.7 lens will permit recording of RCA color television at 24 frames/sec.

The color temperature of the RCA color television receiver image was approximately 6500 K. During the first recording attempt, the following films and filters were tried: Daylight Kodachrome with

Harrison C–¼; Daylight Kodachrome with no filter; Commercial Kodachrome with Wratten No. 83 and Ansco Tungsten with Ansco No. 11 conversion filter.

All exposures were good and the best result was obtained using commercial Kodachrome and the Wratten No. 83 Filter. Strangely enough, it was the consensus of opinion that the film record was superior in quality to the image on the color television receiver as viewed with the naked eye. This phenomenon may be partially explained by the fact that the recording camera lens was located on the axis of, and normal to, the color television image, whereas the observers were force to view the image from an "off center" position.

The amount of light emitted by the RCA "three tube," dichroic mirror receiver, as with the CBS receivers, permitted good exposures to be secured at a light meter reading of from 0.75 to 1.00 foot-candles measured at the recording camera lens with a Model 603 Weston foot-candle meter.

COLOR RECORDING OF CTI COLOR TELEVISION

On March 16, 1950, the first experimental recording of a CTI (Color Television, Inc., San Francisco, Calif.) "line sequential" color telecast was made from an RCA three-tube receiver equipped with dichroic mirrors. This recording was made at 15 frames/sec using the modified Mitchell 16 with the $f/0.7$ lens. The present CTI receiver employs rear projection, the image being viewed on a translucent screen. The resulting image in this case is not as bright as the image that appears on a direct view tube. Color Television, Inc., however, expects to have a new, higher light output tube available for demonstration in the near future.

CONCLUSION

If standard speed ($f/1.4$) lenses are to be used for color television recordings, an increase in color film speed or in television tube light output, or a combination of both amounting to two stops (400%), is necessary. In other words, doubling the speed of presently available color film and doubling the television tube light output would permit recording of color television with $f/1.4$ lenses. The major problem thus far has been that of obtaining sufficient exposure and it will remain so until faster color films or brighter color television tubes become available. The use of high light output projection-type tubes shows considerable promise. The quality of the image produced by

the $f/0.7$ lens cannot compare with the results produced by conventional high-grade motion picture camera lenses. The problems introduced by color television are remarkably similar to those encountered in the three-color film process. The experience and knowledge gained through the widespread use of color films will, without doubt, prove most helpful in solving the problems introduced by both color television and color cinephotography.

ACKNOWLEDGMENTS

The authors are indebted to the following companies and individuals whose co-operation and assistance has made this paper possible: Columbia Broadcasting Co., P. C. Goldmark, John Martin and John Christianson; Smith, Kline and French Laboratories, G. F. Roll and Lewis Lang; Radio Corporation of America, George H. Brown and John Million, Sr.; A. K. Litz, U.S. Navy.

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Non-Intermittent Motion Picture Projection

By WILLIAM C. PLANK

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The numbers and the needs of amateur motion picture projectionists make expedient a restatement or recapitulation of the advantages of non-intermittent motion picture projectors. This is thought necessary on account of the want of due appreciation of the useful characteristics of this type of projector, which the literature published on the subject has revealed.

In a paper entitled "The Problem of Motion Picture Projection from Continuously Moving Film,"[1] a summary of the advantages of non-intermittent projectors was published, which is notable for the number and the importance of those omitted.

Another paper which is believed to undervalue the utility of non-intermittent projectors bears the title, "Is the Continuous Projector Commercially Practical?"[2]

The purpose of this letter is to submit, for the notice of those who require a more adequate amount of data for an appraisal, several additional advantages which were previously passed unnoticed.

In non-intermittent projectors an undisputed advantage is that instead of curtailing the exposure, or stationary period of the image, an additional length of time is assigned to it. The depth, or third dimensional effect brought out by non-intermittent projectors, is believed to be due to the advantage of the lap-dissolve.

Of the useful properties inherent in non-intermittent projectors, one of the most curious is the movement exhibited during a slow lap-dissolve of two successive picture images. As only two film frames take part in the movement, the apparent intermediate positions do not exist in the photographic record; but they are, nevertheless, conveniently introduced by the magic of the lap-dissolve. These movements

REPRINTED: From *Journal of the Optical Society of America*, vol. 39, pp. 505–506; June, 1949; by permission of the Editor.

[1] Fordyce Tuttle and C. D. Reid, *Jour. SMPE*, vol. 20, pp. 3–30; January, 1933.

[2] Lester Bowen and Herbert Griffin, *Trans. SMPE*, No. 18, pp. 147–152; May, 1924.

can sometimes be stopped and started again more than once. In close-ups, the turning of the head or body is often particularly well rendered, with a life-like uniform motion no matter how slowly the change be made. The cause of this curious phenomenon is to be found in the irradiation of the retina. Its greatest advantage to amateurs is that it forms the basis for a successful and inexpensive means of exhibiting slow motion, when the rate of projection is reduced to two or three frames a second, and the taking rates have been at twenty-four or over. The unique slowed motions displayed, and the theory upon which they are based, provide a distinct source of interest and amusement to amateurs.

This useful property of the lap-dissolve is also an important factor in the successful employment of lower rates of projection for amateurs. Many amateur shots can be projected successfully by the non-intermittent projector at rates of from twelve to eight frames a second.

A major advantage, involving higher orders of precision in motion picture registration, is that the registration of the non-intermittent projector can be made as independent of the inaccuracies of the film perforations as the sound track.

The effect of vibration on the definition of the motion picture image is well known. In microscopic work it is very objectionable. In the non-intermittent projector this objectionable feature is avoided because the mechanism has the advantage of operating without vibration.

Graininess, vibration, and errors in registration, are all sources of impairment of the motion picture image, and must be counted among the aberrations. These aberrations still exist and remain a problem in the motion picture image; and optical elements appear to be the only possible means that can be employed to reach and correct them.

Finally, it can be said, the most significant advantage is that the non-intermittent projector lets down the bars and opens the way to new and greener pastures. For, almost within reach, are electrical and photo-electrical means of synchronization, a greatly extended range in rates of projection, higher resolving powers, and larger picture areas.

A Simplified Body-Cavity Camera

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Summary—**The need for a special body-cavity camera in clinical photography is described. Problems in cavity photography are discussed, and diagrams show typical lighting methods. There is an explanation of the Intraflex Camera optical system, the continuous through-the-lens finder and the precalculated iris setting.**

This consideration of body-cavity motion picture photography is confined to the problems of photographing the natural and surgical cavities of the human body which can be made visible to the external camera. These cavities are exposed for photography by the same means as those used by the doctor for visual examination. During an operation, cavities resulting from surgery are held open by various types of clips and clamps: the oral cavity is made visible with the laryngoscope or the throat mirror; the vaginal cavity, by a speculum; the anal cavity, by a speculum or a tubular instrument of the procto-sigmoidoscope type; and the bronci and esophagus by the bronciscope and esophaguscope, respectively.

For visual examination, the areas within these cavities are illuminated by light reflected from a head mirror or by grain-of-wheat lamps attached to the distal end of the scope-type instruments. This illumination, while adequate for examination, is insufficient for motion picture photography.

The first problem of cavity photography, therefore, is that of illuminating the field at some depth within a relatively small passage. This must be done without interference with the camera lens cone of vision which is necessarily positioned coaxially with the cavity. This camera position, in line with the cavity, creates a second problem, that of viewing the field. Any line of sight which will by-pass the camera will be oblique with respect to the cavity; therefore, through-the-lens viewing is indicated. Most 16-mm camera through-the-lens viewers do not provide the continuous viewing essential to maintaining the proper field and focus in cavity photography.

Because of the illumination and viewing problems alone, it is apparent that standard equipment and photographic techniques are

Presented: October 12, 1949, at the SMPE Convention in Hollywood.

limited to the more open and shallow cavities. This is borne out by the fact that many fine surgical films, currently used in medical education, are made with art work to illustrate the photographically inaccessible areas.

Many ingenious methods have been devised and used for body-cavity photography. Three of the more common types are schematically illustrated in conjunction with the problem of photographing a field at the distal end of a rectal proctoscope which is a straight tubular examining instrument about 8 in. long and ¾ in. in diameter.

Figure 1 illustrates a system wherein the light source is positioned as close as possible to the camera lens axis. The effectiveness of this arrangement is limited to the amount of light which can be reflected

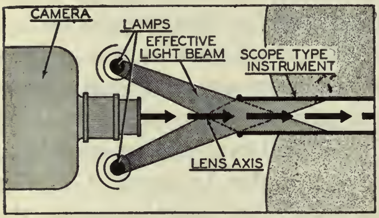


Fig. 1. Use of lamps close to lens.

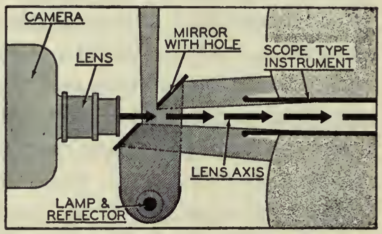


Fig. 2. Use of reflector with hole for lens.

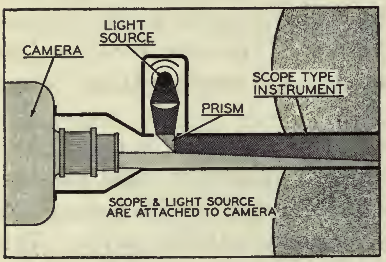


Fig. 3. Prism in camera cone of vision; scope and light source are attached to camera.

through the inside of the tube, as parallax between the light axis and camera axis prevents direct light from reaching the field.

In the arrangement shown in Fig. 2, a mirror with a centrally located hole is positioned coaxially with, and at an angle to, the camera optical axis. Light from an adjacent source is reflected into the cavity by the opaque area of the mirror, and the field is photographed through the hole. In effect, this system is similar to placing lamps close to the lens but offers the advantage of more space for the light

source. A spherical mirror is often used to increase the light concentration at the plane of the field.

Figure 3 outlines a method which is primarily used for directing light into a scope-type of instrument normally attached to the camera

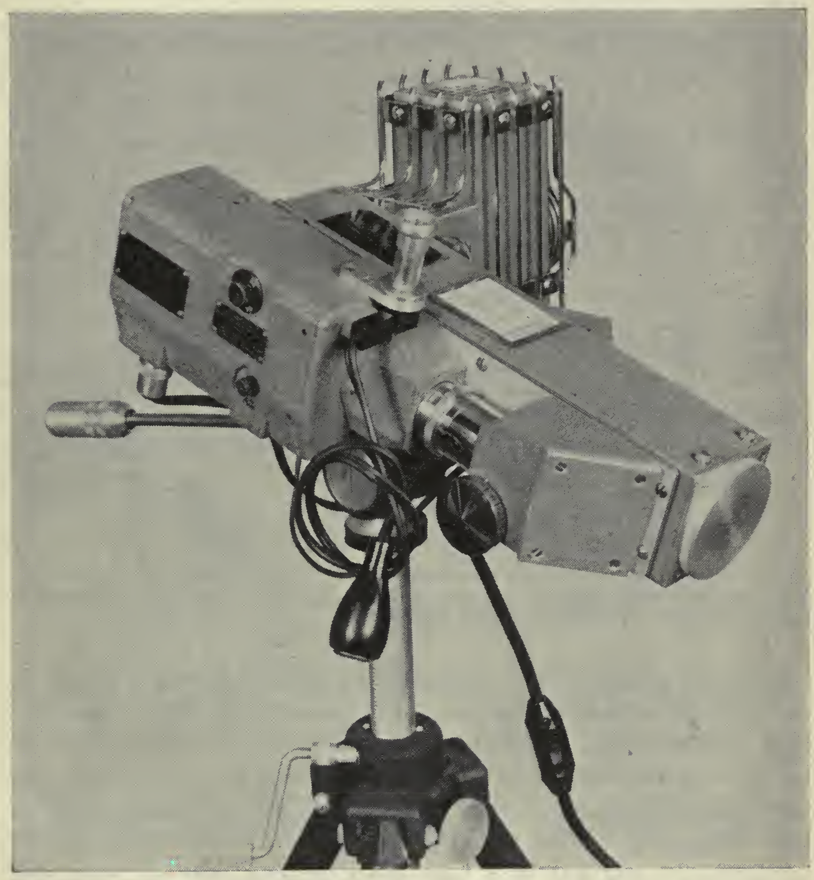


Fig. 4. Model C-3 Intraflex Cavity Camera.

and light source. A mirror or prism, positioned about halfway into the effective camera cone of vision, reflects light from an outside source into the tube. The inside of this tube is highly polished to reflect a maximum of light to the field at the distal end. That half of the camera lens not covered by the prism remains effective. A variation

of this method employs a mirror with a hole to direct light into the scope, and the prism diverts reflected light into a viewfinder.

The Intraflex Cavity Camera is a combination of a 16-mm magazine-loading electric camera and a projection-type light source and optical system (Fig. 4). A beam of collimated light is projected from the unit in coincidence with the camera cone of vision, the two cones being identical in space. The field area illuminated by the beam is identical with the area photographed by the camera and varies in width from 1½ to 4 in. at camera distances of from 10 to 30 in.

Figure 5 is a simplified scheme of the general arrangement of components. Light from a 1000-watt lamp, in the upper left of the diagram, is transmitted progressively through a condenser, 45-degree opaque mirror, 16-mm aperture, projection lens and a special trans-

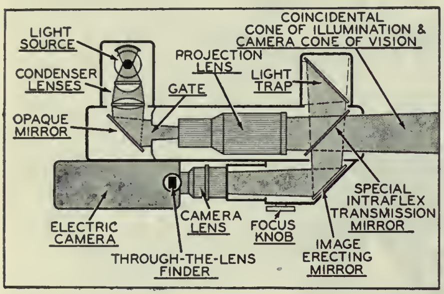


Fig. 5. Simplified scheme of the optical system of the Intraflex Cavity Camera.

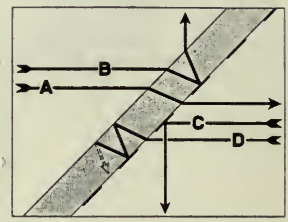


Fig. 6. Intraflex transmission mirror.

mission-reflection mirror. This mirror transmits half of the light to the field and reflects the balance into a nonreflective light trap. The light reflected from the field is diverted from the coincidental axis by the transmission mirror and again reflected into the camera objective by an opaque mirror which normalizes the image right to left. The lamp is offset from the major axis in order that it may be mechanically retained in a base-down burning position when the camera is tilted.

Another special transmission-reflection mirror is positioned in the optical axis between the camera objective lens and the film gate to reflect about one-third of the image-forming light to the ground glass of a magnifying viewfinder. The image formed on this ground glass is in simultaneous focus with the image at the film plane and includes the identical area. This finder remains effective whether the camera

is running or idle and provides a continuous through-the-lens view of the field.

The special transmission mirror used to coincide the cones of illumination and vision is composed of vertical aluminized front surface opaque stripes alternated with clear glass and spaced in such a manner as to prevent the second-surface reflections of the mirror glass from reaching the film. The viewfinder mirror is similar but with a much smaller pattern.

Figure 6 is a schematic cross-section of the transmission-reflection mirror, the heavy lines representing opaque aluminized coating, the lighter lines, clear glass. Line A is a typical ray of light from the projection lens which passes through a transparent area of the mirror to illuminate the field and B is a similar ray which is reflected from an opaque stripe into the nonreflective light trap. C is an image-forming ray, returning from the field, which is reflected into the camera optical system by an opaque stripe. D is a potential image-forming ray which passes through the glass between opaque stripes and is partially reflected by the second surface. This type of ray can cause a ghost image on the film, slightly offset from the major image and of about 4% the intensity. Because of the spacing of the opaque stripes in relation to the thickness and refractive index of the mirror glass, these secondary image-forming rays fall on the reverse side of the opaque stripes and are re-reflected to the second surface. Subsequent reflections are of an order well below the threshold level of the film at the normal exposures and do not record.

Neither the image of the projection aperture nor the image of the field is formed at the plane of this mirror; therefore, there is no stripping of the illumination on the field or on the image at the film plane.

Figure 7 illustrates the Intraflex applied to the proctoscope problem. The camera is positioned coaxially with the scope and light is projected directly onto the field.

Figure 8 is an arrangement for photographing the larynx, posterior nose or any field to which a straight light path does not exist. A mirror is used to direct light to the field, and the camera photographs the reflected image.

The Intraflex is focused by sharpening the image seen on the ground glass screen of the viewfinder. To permit rapid focusing over the relatively large displacement range of the 3-in. lens, a rack and pinion are provided. Rapid focus change is often advantageous when main-

taining sharp focus on instruments moving to and from the camera. The projection lens used in the illumination system automatically focuses the 16-mm light aperture on the same plane as the camera objective by mechanical linkage. This insures even illumination and absence of filament image on the field.

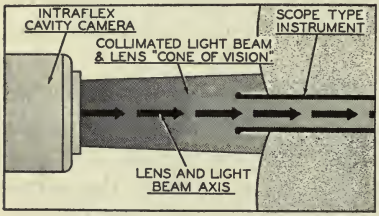


Fig. 7. Using the Intraflex Cavity Camera to photograph a field exposed with a scope-type examining instrument.

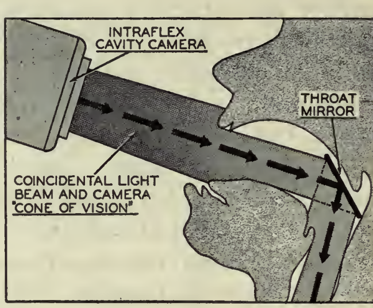


Fig. 8. Photographing the throat.

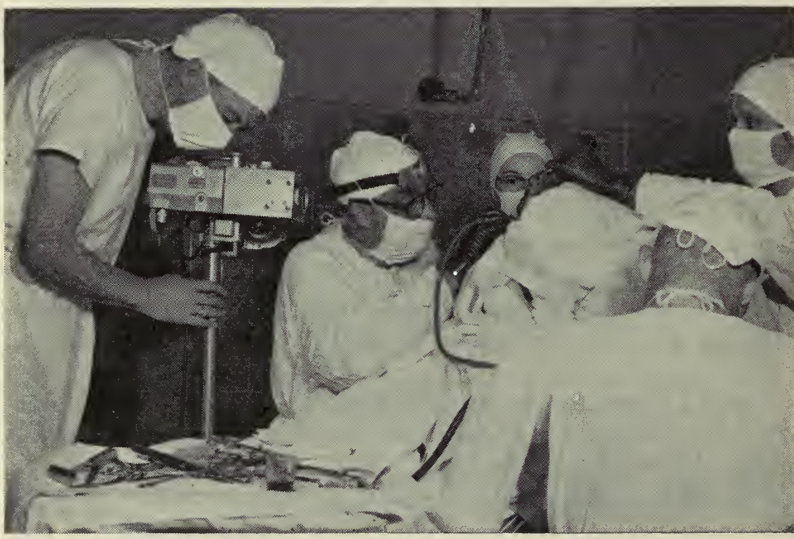


Fig. 9. Model B-3 Intraflex photographing an antro-ethmosphenoidal operation.

Illumination of the field varies only with the distance from the camera. The focusing dial is engraved in alphabetically designated increments which are tabulated on exposure charts for each combination of film and camera speed. After focusing, reference to the indi-

cated letter on the proper chart will designate the correct iris setting. Accurate color values are especially important in medical film.

This camera may be mounted on most types of tripods or cranes. The importance of accurate alignment of camera and cavity indicates the use of a readily and universally adjustable support.

The Intraflex Camera is an effort to solve the cavity photographic problem and to eliminate such technicalities as exposure calculations, distance estimating, camera threading and winding and to make highly predictable results possible for the non-photographically experienced doctor, nurse, or medical assistant.

Even with equipment which simplifies the photographic problem, the cavity photographer will have his troubles, especially in surgical work. The success of the operation or treatment is the primary consideration; the cameraman and his equipment are incidental. Traffic between the camera and the cavity is very heavy in instruments, hands and heads. Shots are made when and if the opportunity prevails. Nine camera starts out of ten are prematurely terminated because of interference. A full-length sequence is the exception. One inch of movement of the patient across the small field will cause the resulting projected image to fly halfway across the projection screen. All in all, the photographer will emerge from the ordeal feeling that he has worked harder than any member of the operating crew.

NOTE: The color motion picture which illustrated this paper contained sample footage of most of the body cavities together with a complete filming of the "Transantral Surgical Route to the Sphenoid Sinuses." According to the surgeon who originated this now widely used technique some twenty years ago, this was the first successful motion picture of the operation. The entire procedure was filmed through an opening ¾ in. in diameter in the anterior wall of the antrum, under the upper lip, and progressed into the head to a point at the intersection of a line between the temples and one extending backward from the bridge of the nose, an area very close to the exact center of the head (Fig. 9).

16-Mm and 8-Mm Motion Pictures Committee Report

By H. J. HOOD, Chairman of the Committee

It is some time since your 16-Mm and 8-Mm Motion Pictures Committee has made a formal report; however, that is no indication of inactivity. For at least the past couple of years, most of the Committee effort has gone into the development of engineering standards. One of the first projects brought to a successful conclusion by the present Committee was a group of four American Standards establishing dimensions for picture apertures in cameras and projectors, published in the April, 1950, Journal. Now nearing the end of the long, and sometimes rocky, trail leading to approval as an American Standard are proposals relating to a uniform zero point for focusing scales on 16-mm and 8-mm cameras, mounting threads and flange focal distances for camera lenses, A and B windings for 16-mm film raw stock with perforations along one edge, 16-mm motion picture projection reels, splices for 16-mm films for projection and edge numbering of 16-mm film.

Many of you will remember an outstanding paper on sprocket design published in the June, 1947, Journal. When this Committee studied the possibility of incorporating the technical material in that paper in a Standard, the conclusion was reached that it was not suitable for standardization even though it would be useful to the very men who are likely to keep a book of Standards at hand. This dilemma led directly to approval, by the Society, of the scheme of printing the sprocket design data, and possibly other suitable technical matter, in the Standards' format but labeled "Recommendations" to indicate that it is engineering information rather than a formal standard.

A large subcommittee, under the leadership of E. W. D'Arcy, is working diligently on standards for 16-mm sound reproducer characteristics. That undertaking has turned out to be virtually a research project. Several group "listening tests" and discussions have been carried out. Wide circulation of tentative recommendations can be expected soon. One purpose of this proposed recommendation is to

Presented: April 27, 1950, at the SMPTE Convention in Chicago.

establish, for the equipment used in reviewing 16-mm sound films, a quality level which will eliminate from the appraisal what we might call the "allowance for equipment" factor.

Our Committee is getting well started on drafting standards for projection lamp bases. This is a most timely project as an improved design is necessary, particularly for the new professional and semi-professional projectors. On April 26 representatives of the lamp and projector manufacturers met and agreed on the basic outlines for the new lamp. Unless there is some unexpected difficulty, this standardization should be accomplished fairly quickly.

As the projects listed above are brought to a conclusion and removed from our agenda, others will take their place. For example, a start has been made on standards for camera spools, 8-mm projection reels, 8-mm splices and 16-mm laboratory-type splices.

Also regarding standards, we should note the increasing amount of explanatory material incorporated in several of the standards mentioned above. This is believed to be a desirable trend.

Outside of the field of standards, our Committee has had one major undertaking on its books for quite a while: the writing of a new edition of the booklet on projection practice published in 1941 as a JOURNAL reprint. Our lack of accomplishment in this direction may be attributed to the concentration most of us have had to apply to catching up after the war. We won't be able to use that alibi much longer.

At the last meeting of this Committee, in New York on January 31, there was preliminary discussion which may lead to three new test films.

This Committee has a wide field in which to range. While we have made a conscious attempt to maintain a diversified membership, there is always a chance that we will overlook some project we should consider. In short, we invite your suggestions and comments.

Screen Brightness Committee Report

By W. W. LOZIER, Committee Chairman

The last report of this Committee was presented at the October, 1947, meeting of the Society and published in the March, 1948, Journal. That report told of the survey by the Screen Brightness Committee on 18 theaters of various sizes and locations. That survey brought forth interesting and important indications of theater practice and the need for more extensive study; however, a further survey was postponed until more suitable instruments were available, it having been decided that visual type meters requiring a subjective photometric balance are inherently unsuited to this task.

Specifications and Methods

The Committee has undertaken the task of writing performance specifications on meters for photometric measurements of motion picture screens and also formulation of methods of measurement using these meters.

It is realized that the screen brightness problem involves three elements.

(1) Incident illumination, generally measured in foot-candles.

(2) Screen reflection factor, generally expressed as ratio to a perfectly diffusing and reflecting screen.

(3) Reflected screen brightness, generally measured in foot-Lamberts.

These three quantities are connected by the following relation:

$$\text{Screen Brightness} = \text{Screen Reflection Factor} \times \text{Screen Illumination}.$$

The measurement of any two of the above three quantities will permit calculation of the third. The measurement of incident illumination on theater screens is a relatively simple procedure for which satisfactory meters are available. It is the measurement of one or the other of the remaining two quantities, that is, screen reflection factor or reflected screen brightness, which presents the major problem.

Presented: April 27, 1950, at the SMPTE Convention in Chicago.

Measurement of Screen Brightness and Screen Illumination

The Committee has worked with instrument manufacturers with the goal of obtaining combination meters suitable for measurement of incident screen illumination and reflected screen brightness. Progress has been carried to the point where it has been shown that portable meters of desired sensitivity can be built. However, because of the requirements for a rather sensitive meter element for measuring the photoelectric current, it appears doubtful whether the cost can be reduced to that for a simple foot-candle meter or to a level low enough to bring about widespread distribution and usage.

Screen Reflectivity Meters

Further efforts are being made along the lines of some method which will measure incident illumination by means of an inexpensive meter and will also determine screen reflection factor. Measurement of these two quantities would permit calculation of the screen brightness as simply their product. It may be possible to develop a simple apparatus for determining the screen reflection factor which will employ the same meter as that used for measurement of incident screen illumination.

Extension of Theater Screen Brightness Survey

The Committee has been asked to extend the screen brightness survey to approximately 100 theaters to obtain a cross section of theater screen lighting practice. Plans for conduction of this survey are now being made.

Preferred Screen Brightness Levels

The Committee is looking into the problem of preferred screen brightness levels in indoor and outdoor theaters. As a preliminary step, a survey is being made of the pertinent scientific work already done on this problem. If the necessary scientific information is not available, consideration will be given to formulation of tests and experiments which will provide information basic to rational determination of preferred screen brightness levels under various conditions.

Engineering Committees

The semiannual conventions of the Society offer an opportunity for the engineering committees to meet and carry on their work with considerably greater ease than at other times of the year. During the week of the 67th Convention in Chicago, nine engineering committee meetings were held with nearly 100 members in attendance. A few of the highlights of these meetings follow:

16-Mm Projection Lamps

An outstanding example of the industry's co-operation to achieve standards in the best interests of the consuming public has been the work on projection lamps by the 16- and 8-mm Committee. Under the leadership of Henry Hood, the manufacturers of incandescent projection lamps and the 16- and 8-mm projector manufacturers got together to discuss the possibility of establishing one standard for the recently introduced medium-focus, base-up lamps.

Prior to this meeting, two manufacturers, namely General Electric and Bell & Howell, had proposed designs for the mounting dimensions for this type of lamp. Both companies, however, in the interests of establishing one standard, agreed to dedicate their patent rights to the public if the Committee decided to accept their design as the standard. As it turned out, the G.E. proposal was accepted and outline drawings giving the pertinent dimensions have been distributed to the Committee for ballot action.

16-Mm Sound Reproduction

Ever since the war, manufacturers have been trying to improve the quality of 16-mm projectors. Recently, three new models of high professional quality have been introduced. If these new projectors are ever to receive wide acceptance, the general commercial quality of 16-mm release prints will have to be improved. To meet this end, the Committee under E. W. D'Arcy has been at work for almost two years trying to establish standard review room conditions for judging the quality of such prints.

At the meeting in Chicago, it was agreed to revise an earlier draft of these recommendations so as to specify not only the frequency response characteristics of such a system but also the acoustical qualities of the various review rooms and other pertinent requirements for the reproducer itself. A revised draft incorporating these changes is now in the hands of approximately 80 people who are qualified to judge its acceptability. If no adverse criticisms are received within the next 30 days, it will be published in the Journal and publicized as widely as possible in the hopes that 16-mm producers and processing laboratories will adopt these recommendations as a quality control measure.

Film Dimensions

Over the past 30 years there have been many discussions within the motion picture industry concerning the desirability of establishing a single perforation for both positive and negative 35-mm film. Since 1916 there have always existed at least two types of 35-mm perforation. Recently, however, with the increased interest in color, the whole question has again been under review by the Film Dimensions Committee under Dr. E. K. Carver's chairmanship. In April, 1949, the Committee recommended the adoption of the so-called Dubray-Howell per-

foration, as the single standard, and it was described in the JOURNAL of that month.

Shortly after publication, however, Ansco pointed out that while this proposal was probably superior to present practice, there might be a perforation which was even better and Ansco proposed another design. At the Chicago Convention, Ansco representatives presented extensive test data, indicating that their proposal may be superior and certainly throwing doubt on the advisability of tying off on any new standard too quickly.

Consequently, further tests will be run by Ansco as well as by the Motion Picture Research Council in an attempt to determine the most desirable design. It was strongly urged by all concerned, however, that these tests be conducted as rapidly as possible since there may never be another opportunity to replace the two present standards with a single standard satisfactory for both negative and positive films. W. V. Wolfe, President of the Research Council, warned that even a delay of six months may be too long since many of the new color processes are already adopting standards.

Society Announcements

Dues payments from outside the United States must be made in U.S. dollars. The dues payments of all new members after July 1 are required to be in U.S. dollars; and, of course, all payments of annual dues are subsequently to be made in U.S. currency.

June brings graduates—we are reminded by our Student Chapters at New York University and at the University of Southern California, and also by some interesting information from the Rochester Institute of Technology.

For information about Society student members being graduated, or about students seeking summer work, the industry is advised to write:

New York University: Faculty Adviser, Dr. Robert Gessner, Washington Square College of Arts and Sciences, New York University, Washington Square, New York 3.

University of Southern California: Faculty Adviser, Mr. Wilbur T. Blume, Acting Head, Department of Cinema, University of Southern California, 659 W. 35 St., Los Angeles 7, Calif.

Rochester Institute of Technology: C. B. Neblette, Supervisor, Department of Photographic Technology, Rochester Institute of Technology, Rochester 8, N.Y.

The courses at New York University are given to provide basic cultural training in the liberal arts and sciences and an introduction to, and orientation in, the interpretive problems of motion picture writing and production.

The University of Southern California provides fundamental orientation in the principles of photography and in the tools and techniques of the motion picture profession. There are courses on the philosophical aspects and aesthetics of the film and there is advanced training in production techniques including camera equipment, sound recording, production supervision and the responsibilities of the director, as well as a practical workshop giving guidance in the actual preparation of educational films.

Graduates in photographic technology are coming from the Rochester Institute of Technology. Mr. Neblette of the Institute's Department of Photographic Technology advises that among 94 men and 3 women being graduated in June there are 20 hoping to locate in positions as color technicians doing dye transfer printing, color processing, etc., and 11 in the visual aids field. This Institute class includes for the first time students from the courses in Preparation of Visual Aids, Illustrative Color Photography and Processes of Color Photography. Other students have favored other fields with courses in Portrait, Commercial and Industrial Photography, Offset Lithography and Photographic Technology.

The wrong Journal reached a number of members, mostly along the West Coast. They were somewhat surprised when they received the *Journal of Accountancy* in the wrapper of the April issue of the JOURNAL of our Society. This error on the part of the printer is regretted and we wish to offer immediate replacement of any *Journals of Accountancy* which were received but have not as yet been reported.

Papers Committee

The members of the Papers Committee are now training their sights on the program for the 68th Convention at the Lake Placid Club in October. In the light of program crowding at the last three or four conventions, the Committee has made certain changes in the technical session format and in the Papers Program schedule. Because nearly all papers offered for presentation at several recent conventions were accepted, the Papers Program was filled to the limit with nearly every available moment taken up with their delivery, leaving little if any time for the audience to discuss with the author details of the subject. This has been unfortunate because it is at cross purposes with one of the major reasons for holding conventions. Members should be given an opportunity to express themselves or report on work that they or their companies have been doing, and then should be given a chance to discuss the relative merits of their ideas or proposals, making the discussion time of paramount importance.

The quantity and scope of papers offered for presentation parallels the growth and diversification easily apparent in the Society's engineering committee work, and in the editorial content of the JOURNAL. Assuming that these highly desirable trends will continue, the problem of program crowding will certainly not solve itself, and therefore the Papers Committee has decided to use a somewhat different philosophy in accepting papers for the 68th Convention. All offerings will be considered and the most outstanding will be scheduled for actual presentation at the convention. All manuscripts whether or not presented at the Convention, will be submitted to the Board of Editors through conventional channels. A number of them will no doubt be recommended for presentation at Section meetings or in the event that a group of high-caliber papers on related subjects is available, they may be offered at one or more regional conferences during the year.

The actual Papers Program for the 68th Convention will be limited to three, four or five papers per session, with sufficient discussion time scheduled in advance to make convention week a worth-while investment for engineers who are seriously concerned with the subjects on the program. It is expected that points not covered initially by the author but which arise during subsequent discussion or correspondence will either be incorporated within the final JOURNAL version of the paper or will be added to it as formal discussion of the question and answer type.

Section Meetings

Atlantic Coast

Society members who live in or near New York and were unable to attend the 67th Convention turned out in force on May 24 for the regular monthly Atlantic Coast Section Meeting. They heard a repeat performance of Richard S. O'Brien's paper "Engineering Aspects of Television Studio Staging and Lighting Practices," presented previously at the Convention in Chicago. The Section meeting was held at the Reeves Sound Studios, where Mr. O'Brien of the General Engineering Dept., Columbia Broadcasting System, described a number of rules formulated by the major television production groups at CBS to provide a well-integrated basic program production plan. This systematic organization of staging, lighting, camera operation and direction is assurance in advance that the resulting pictures will be as technically correct and as pleasing as the combined limitations of the television system will allow.

The next meeting of the Section is scheduled for June 28th, with a paper by Robert Cavanagh, Research Engineer for Allen B. DuMont Laboratories: "Telecasting of 16-Mm Film, Using the New Holmes Fast Pull-Down Projector on an Image Orthicon Camera." Television broadcasters and engineers interested in 16-mm equipment and film problems will do well to keep posted on this further step in the direction of television-film evolution.

Pacific Coast Section — USC Student Chapter

Making a break from the conventional, members in the Pacific Coast Section joined with the Student Chapter at the University of Southern California on Tuesday evening, May 16, in presenting the annual dinner meeting of the Section. Held at the USC Department of Cinema, the two groups and a substantial contingent of the Audio Engineering Society enjoyed a buffet dinner, three papers by students and Faculty of the University, and a tour of the Department of Cinema.

Following the dinner, the program opened with remarks by C. R. Daily, Section Chairman, and a showing of the film *Troy A.D. 1950*. The three papers were: "The USC Department of Cinema" by Bernard Kantor; "Construction of a 16-Mm Bolex Camera, Incorporating Design Features Found in 35-Mm Studio Cameras" by John Raymond; and a description by Dan Chapman of the production techniques involved in producing *The Thinnest Slice*, a film made for the School of Medicine showing the development of a technique for slicing organic tissue for observation and photography under the electron microscope. A showing of the film concluded this part of the program.

The Pacific Section has its June meeting arranged well ahead of time. A paper prepared by J. G. Frayne, E. W. Templin and G. R. Crane, "A Professional Magnetic Recording System For Use with 35-, 17½- and 16-Mm Films," will be presented in the Institute of Aeronautical Science Auditorium at 8:00 P.M., Tuesday, June 13. This is another meeting with the Audio-Engineering Society members in the Hollywood area on a topic of interest to both groups. It will be the first description of a new Westrex Magnetic Recording Channel designed particularly for motion picture television and allied fields of sound recording. The complete system will be described in detail and demonstrations of recordings will be given.

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 31, no. 3, Mar. 1950

Matts, Miniatures and Meticulous Cinematography (p. 82) F. Foster
Magnetic Recording Boon to Budget Film Production (p. 84) D. Harrold
The Men Who Light the Sets (p. 85) G. Taylor
Something New in Color Temperature Calculators (p. 88) R. Lawton
New Eastman Color Film Tested by Hollywood Studios and Film Labs. (p. 95)

vol. 31, no. 4, Apr. 1950

Filmed Inserts and Special Effects Aid Live TV Shows (p. 124) H. A. Lightman
Mitchell Announces New Professional 16mm Projector (p. 134)
Bell & Howell's New Professional 16-mm Camera (p. 134)

Audio Engineering

vol. 34, no. 3, Mar. 1950

Magnetic Recording in Motion Pictures (p. 9) M. Rettinger

vol. 34, no. 4, Apr. 1950

Magnetic Recording in Motion Pictures (p. 18) M. Rettinger

British Kinematography

vol. 16, no. 2, Feb. 1950

The Heating of Film and Slides in Projectors (p. 38) H. McG. Ross
The Application of Magnetic Recording to Sub-Standard Film Projectors (p. 55) K. G. Gould and R. I. T. Falkner

vol. 16, no. 3, Mar. 1950

Acoustics and the Film
I. Optimum Period of Reverberation (p. 73) C. W. Glover
II. Acoustic Design of Studios (p. 77) J. McLaren

Progress Report on Colour Kinematography (p. 83) J. H. Coote
Trends in Studio Lighting Equipment
I. Light Control Gear (p. 91) L. Hewins
II. Carbon Arcs (p. 91) C. G. Heys Hallett
III. Mercury Cadmium Compact Source Equipment (p. 93) H. K. Bourne

International Projectionist

vol. 25, no. 3, Mar. 1950

The Geneva Intermittent Movement (p. 7) A. C. Schroeder
The 35-mm Projection Positive Film, Pt. V (p. 15) R. A. Mitchell

vol. 25, no. 4, Apr. 1950

The 35-mm Projection Positive Film, Pt. VI (p. 7) R. A. Mitchell
Renewed Interest in the Maskless Screen (p. 11)
The Geneva Intermittent Movement (p. 14) A. C. Schroeder
Heating of Film by High-Intensity Arcs (p. 17) H. McG. Ross

Photographic Journal

vol. 90A, Special Number, Apr. 1950

Progress in Kinematography (p. 126) R. H. Cricks

RCA Review

vol. 11, no. 1, Mar. 1950

Characteristics of High-Efficiency Deflection and High-Voltage Supply Systems for Kinescopes (p. 5) O. H. Schade
Adjustments for Obtaining Optimum Performance in Magnetic Recording (p. 38) A. W. Friend

Tele-Tech

vol. 9, no. 5, May 1950

RCA Color Kinescope Demonstrated (p. 20)
Magnetic Sound on 8mm Film (p. 25) M. Camras

Tele-Vision Engineering

vol. 1, no. 4, Apr. 1950

Television Optics (p. 4) F. G. Back

New Members

A new effort in the services of the Society is this listing of new members. Below are those added to the rolls during April, since the 1950 MEMBERSHIP DIRECTORY went to press. Also listed below are those members whose grade has been changed during this period.

It is hoped that this list each month will serve to introduce new members not only to the Society generally but also to their Section Officers and especially to those with common geographical and industrial locations.

The designations of grades are the same as those in the DIRECTORY:

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

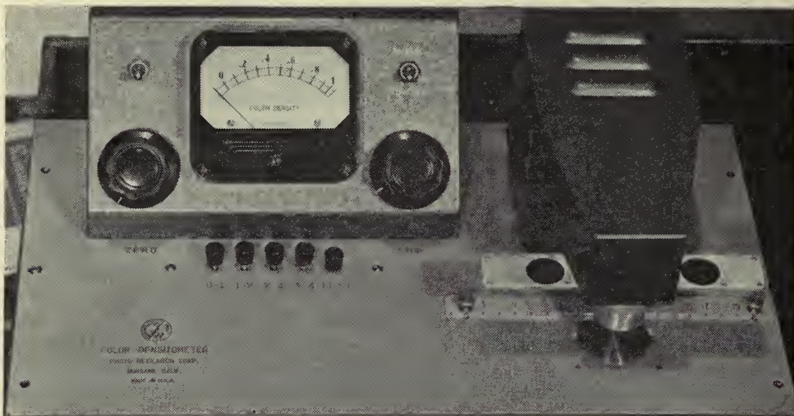
ASAKURA, AKIRA, 258 E. First St., Los Angeles 12, Calif. (S)
BERLANGA, JULIO A., Artes No. 13-A, Mexico, D.F., Mexico. (A)
CANNAN, WILLIAM A., 262 North Drive, Rochester 12, N.Y. (A)
CONDIT, WARREN L., 37 Lakeview Ter., Staten Island 5, N.Y (A)
CORRADI, AMERIGO, Via Albalonga 38, Rome, Italy. (A)
COWETT, PHILIP M., 1521 Tyler Ave., Falls Church, Va. (A)
DEBISH, JEROME E., 5353 W. Cullom Ave., Chicago, Ill. (A)
DePAUW, HARVEY K., 2298 W. 20 St., Los Angeles, Calif. (S)
ELLEN, ROBERT I., 5555 Hollywood Blvd., Hollywood, Calif. (S)
EWING, JOHN S., 12690 Elmwood Ave., Cleveland, Ohio. (A)
FAYMAN, LYNN C., 5655 La Jolla Blvd., La Jolla, Calif. (A)
GREENWOOD, JAMES H., 166 N. Sprague Ave., Pittsburgh 2, Pa. (A)
HAINES, WILLIAM H., Electric Specialty Co., Stamford, Conn. (A)
HAUGE, CARL W., 9933 Provo Ave., Tujunga, Calif. (A)
HENIGSON, ROBERT, 342 N. Highland Ave., Los Angeles 36, Calif. (A)
JARMAR, SVEN, Filmstaden, Solna, Sweden. (A)
KAGE, EARL W., 217 Elm Tree Rd., Rochester 12, N.Y. (A)
KOLBER, JOSEPH, 168 W. Kirkwood Ave., Merrick, L.I., N.Y. (M)
KRAMER, AMBROSE W., P.O. Box 588, Alexandria, Va. (M)
KRUSE, WILLIAM P., 5751 W. Newport, Chicago 34, Ill. (A)
LATIERE, LUCIEN, 151-08—33 Rd., Flushing, N.Y. (M)
LEVANTINIER, SHARLE, 1725 N. Normandie Ave., Hollywood 27, Calif. (S)
MARSHALL, CHARLES T., 4427 N. Winchester, Chicago, Ill. (A)
MILLER, ROBERT W., DeVry Corp., 52 Vanderbilt Ave., New York, N.Y. (A)
MORE, EDUARDO, Calle 27, No. 908, Vedado, Havana, Cuba. (M)
MORRIS, C. W., Western Theatrical Equipment Co., 337 Golden Gate Ave., San Francisco, Calif. (A)
NIEMANN, H. P., 12690 Elmwood Ave., Cleveland 11, Ohio. (M)
O'CONNELL, LEON J., 2265 Sedgwick Ave., New York 53, N.Y. (A)
PERRY, RICHARD A., 1723 Harvard Ave., Independence, Mo. (A)
PETERS, PAUL, 317 West Cowan Dr., Houston 7, Tex. (A)
REICH, ROBERT L., 5 Legion Pl., Malverne, L.I., N.Y. (M)
RODELIUS, NELSON W., 2749 Reese Ave., Evanston, Ill. (A)
ROSE, JAMES M., 240 E. 22 St., New York, N.Y. (A)
SWEENEY, DONALD E., 1027 W. 94 St., Los Angeles 44, Calif. (S)
TREVOR, DON-MARC, 825 W. 180 St., New York 33, N.Y. (A)
YOUNG, IRWIN W., 100 Andover Rd., Rockville Centre, N.Y. (A)
WALKER, JOHN J., 414 Arbor Ave., Highland Park, Ill. (A)
WRAY, WILLIAM C., 5018 S. Kedvale, Chicago, Ill. (A)

CHANGES IN GRADE

BLUME, WILBUR T., 15223 Ermanita St., Gardena, Calif. (S) **to** (M)
WYBROW, ERIC, 10435 Dunlear Dr., Los Angeles 64, Calif. (A) **to** (M)

New Products

Further information concerning the material described below can be obtained by writing direct to the manufacturers. As in the case of technical papers, publication of these news items does not constitute endorsement of the manufacturer's statements nor of his products.



The Color Densitometer above has been developed by Photo Research Corp., 127–129 W. Alameda Ave., Burbank, Calif. It is for measuring over-all color density as well as the effective density of each of the color layers in color film.

The density of the individual exposures of the sensitometric strip are read on the densitometer and are plotted against the individual steps which produced them. When these plotted points are connected by a smooth curve, there is obtained the H & D characteristic curve of that particular film or emulsion. Such curves are used as a guide in the determination of proper lamp current, developing solution and processing time and temperature.

In the case of subsequent laboratory operations — duping, the making of separation negatives, printing and optical work — the number of possible applications becomes much greater. If the color original is not in perfect balance, corrective measures will be applied at this stage, and in order to apply these intelligently it is necessary to know the density range in the three bands employed, blue, green and red, as well as to know the diffuse density reading of masks. If the original is in balance, such information is necessary to insure retention of this condition in future copies. For such purposes an ordinary densitometer is of little assistance, and it is for these that the PRC Color Densitometer has been created.

SMPTE Officers and Committees: The roster of Society Officers was published in the May Journal. The Committee Chairmen and Members were shown in the April Journal, pp. 515–22; changes in this listing will be shown in the September Journal.

The Gibbs Photodont is here shown on a dental bracket table with a Kine Exakta V Camera, for which the exclusive U.S. distributor is Exakta Camera Co., 46 W. 29 St., New York 1. This unit is designed for dentists and doctors, to secure intraoral Kodachromes and for photographing in the specialties of dermatology, plastic surgery and opthalmology. The built-in light unit is independent of the flexible camera mount, and, to minimize patient discomfort, the two lamps in a fixed position glow at a low intensity except at the moment a picture is being taken. This unit has a retail price of $59.50.

Letters to the Editor

I have read with interest the article appearing in the March JOURNAL, entitled "Spontaneous Ignition of Decomposing Cellulose Nitrate Film."

There is no doubt, as the authors state, that deterioration of film caused mainly by faulty processing can be a source of spontaneous combustion, but this does not tell the entire story. Spontaneous fires can also start in cellulose nitrate film without the preliminary warnings detailed in the excellent photographs appearing in the article.

We recently had a fire which took place with comparatively new film in which the gelatin had been removed by our usual washing process and we know that this film was clean and free of any extraneous matter when it ignited.

My contention is that cellulose nitrate can contain higher degrees of nitration than is wanted for film and this higher nitration at times is one of the causes of spontaneous combustion, particularly with elevation of temperatures. I realize that this is an alarming statement, but it is borne out by my experience. The remedy is that the film should, therefore, be stored under proper conditions.

For one thing, film should not be stored in iron drums, as they are conductors of heat and rapidly transmit the heat from one drum to another in a vault filled with such drums.

The fundamental thing in designing vaults and containers, and in storing nitrate film, is insulation, not conductivity. Insulation is obtained by separating quanti-

ties of film one from the other with a nonconductor, such as asbestos, wood, cardboard, plastics and other insulating material. Conductivity is obtained by storing the film in metal cans, on metal shelves, and in metal containers, such as steel drums. In other words, film should be kept away from metal as far as is practical and surrounded only by nonconductors such as those enumerated.

If under these ideal conditions a film does ignite or explode, due to deterioration from one cause or another, the fire is then confined to a small area.

April 13, 1950 JOSEPH H. SPRAY

Re: Mr. Spray's letter above.

We do not doubt that, under certain unusual conditions, new film can ignite spontaneously. Spontaneous ignition is the result of two phenomena, heat generation and heat dissipation. Heat is usually generated by some exothermic chemical reaction and is dissipated by conduction, radiation, and connection to the surroundings. When the rate of heat generation exceeds that of heat dissipation, the temperature of the material rises until ignition occurs. We understand that in Mr. Spray's plant the emulsion was removed from cellulose nitrate base film by washing in a hot caustic soda bath. The washed film was then cut to lengths and packed. The soda-ash residue that remains along with the film may react with it to generate more heat than is usually the case. Also, because of higher temperatures which prevail in certain parts of the plant, heat may not be dissipated as rapidly as desired. Under such conditions, material may self-ignite when it would not do so in normal storage. The paper, "Spontaneous Ignition of Decomposing Cellulose Nitrate Film," was written with an eye toward the prevention of fire in libraries and film exchanges. We still believe that under conditions prevalent in such installations, new film will not self-ignite.

The correspondent's contention that excessive nitration may be a cause of spontaneous ignition is interesting and should not be dismissed without careful study. However, there is the belief that because of the modern quality control methods used in the manufacture of nitrate film a uniform product results. Besides, if variation in the degree of nitration does exist, it has not been proven that the autogeneous ignition temperature will be affected. These two factors would have to be studied to confirm or deny the correspondent's hypothesis. We do know that Bureau of Standards investigators were unable to cause the spontaneous ignition of new film at ambient temperatures of up to 120° F.

We wholeheartedly agree with Mr. Spray that all nitrate film should be stored in insulated facilities under controlled temperature conditions. Engineers of the Interagency Committee for Nitrate Film Vault Tests have devised insulated racks which can, without the aid of sprinklers, contain a film fire to the reel in which it originated. Organizations storing quantities of nitrate film should consider, as a long-range project, the equipping of their facilities with this type of rack. Such a program may take years to execute, however, and will not reduce the danger of film fires in the near future. For that reason we recommend that procedure as outlined in the paper as being the only practical first aid solution to the problem for the immediate future.

June 12, 1950 JAMES W. CUMMINGS

Employment Service

POSITION AVAILABLE

Wanted: Individual who has had practical paid experience in the audio-visual field; must have knowledge of film storage procedures, circulating and maintenance of film, evaluation and catalog preparation. Must be able to meet the public and to supervise. Write: R. E. Herold, 5069 Montezuma St., Los Angeles 42, Calif.

POSITIONS WANTED

Cameraman - Director: Thorough knowledge of script-to-screen technique. Capable of own script preparation and production; 6 yr experience free-lance cameraman and producer; adept with all types 16-mm photographic and editing equipment. Wish permanent position with 16-mm industrial or TV producer; age 27, single, free to travel, details readily supplied. Robert Deming, 343 S. 13 East, Salt Lake City, Utah.

With 35-Mm Production Unit: Young veteran desires to learn motion picture production. Will work in any capacity. Single, 23, with 8 yr theater experience, all phases; mgr small house 3 yr; 2 yr A.M.P.S. projectionist supervisor; grad. AAF Photo School and Motion Picture Inst. production course. Have private library of over 200 film books; serious student of films since 15. Currently employed; detailed letter and refs readily supplied; salary no object. John P. Lowe, 265 State St., Northampton, Mass.

Producer-Director-Editor: 10 yr with major film producers. Thorough knowledge and experience script-to-screen production technique: directing, photography, editing, laboratory problems, sound recording, 35- and 16-mm, b & w. Specialist in research and production of educational and documentary films; small budget commercial and TV films. Long experience in newsreels. Desire greater production possibilities, go anywhere. Member SMPTE, top refs. E. J. Mauthner, P. O. Box 231, Cathedral Sta., New York 25.

Mechanical-Electronic Engineer: B.S. degree in Mechanical Engineering; extensive design, mfg. experience, standard and drive-in theater picture and sound equipment; experience as engineering assistant to top management exec. corp. in radio TV. Write A. Kent Boyd, 3308 Liberty St., Austin, Texas.

In Manufacturing: Broad experience in developing, improving and producing of home movie cameras and projectors. Good technical background. Desire position with mfr. Earle F. Orr, 345 Fellsway West, Medford, Mass.

On-the-Job G.I. Bill Training: Ambitious young man to be member of camera crew; grad. U.S. Army Signal Corps Schl.; experienced with Cine Spec., 70DA, Eyemo, Wall and Mitchell cameras; studied editing, art directing and cinematic effects at U.S.C.; married, non-drinker, serious; man for small studio TV work. P.O. Box 524, Alhambra, Calif.

TV and Motion Picture Production Supervisor: 18 yr of unusually complete and varied experience in production of films for theatrical, educational, commercial and TV fields. Heavy technical background in animation, special effects, optical printing, stop-motion, as well as live action. Installed five animation and special effects departments now in operation. Chief cinematographer on U.S. Govt. training films. Experience covers Technicolor, b & w, 35- and 16-mm. Good laboratory background. Would like executive liaison position to supervise production, where creative ability and knowledge of lesser-known techniques could be utilized. Will travel anywhere within U.S. Member of SMPTE for 15 yr. More detailed résumé and references supplied on request. Ernest M. Pittaro, 1930 Grand Concourse, Bronx 57, New York.

Papers Presented at the Chicago Convention, April 24-28

Listed by Sessions

MONDAY NOON

Spyros P. Skouras, 20th Century-Fox Film Corp., New York, N.Y., "Television and the Motion Picture Theater."

MONDAY AFTERNOON

Edwin C. Fritts, Camera Works, Eastman Kodak Co., Rochester, N.Y., "A Heavy Duty 16-Mm Projector."

George J. Koch, Camera Works, Eastman Kodak Co., Rochester, N.Y., "Interference Mirrors for Arc Projection."

James A. Moses, Army Pictorial Service Division, Washington, D.C., "Armed Forces 16-Mm Film Program."

Frank P. Herrnfeld, Ansco, Hollywood, Calif., "Flutter Measuring Set."

Loren L. Ryder, Paramount Pictures, Hollywood, Calif., "Motion Picture Studio Use of Magnetic Recording."

Walter T. Selsted, Ampex Electric Corp., San Carlos, Calif., "Lip-Synchronous Recording on Standard Unperforated Magnetic Tape."

M. Rettinger, RCA Victor Division, Hollywood, Calif., "A Magnetic Record-Reproduce Head."

Edward P. Kennedy, Squier Signal Laboratory, Ft. Monmouth, N.J., "New Sound Film Stabilizing System for 16-Mm Recording and Reproduction."

John J. McCormick, Navy Motion Picture Exchange, Brooklyn, N.Y., "U.S. Navy 16-Mm Review Room Characteristics."

MONDAY EVENING

Frank H. McIntosh, Consulting Engineer, Washington, D.C., "The Properties and Characteristics of Color Television Systems Proposed to F.C.C."

John R. Howland, Zenith Radio Corp., Chicago, Ill., "Phonevision Progress."

TUESDAY MORNING

W. R. Fraser and G. J. Badgley, Naval Photographic Center, Anacostia, D.C., "Motion Picture Color Photography of Color TV Images."

Arthur B. Bronwell, Northwestern University, Evanston, Ill., "Critical Evaluation of Color Television."

Constantin S. Szegho, The Rauland Corp., Chicago, Ill., "Color Cathode Ray Tube with 3 Phosphor Bands."

F. N. Gillette and J. S. Ewing, The Hertner Electric Co., Cleveland, Ohio, "Component Arrangement for a Versatile Television Receiver."

France B. Berger, General Precision Laboratory, Inc., Pleasantville, N.Y., "Characteristics of Motion Picture and Television Projection Screens."

E. Arthur Hungerford, Jr., U. S. Navy Special Devices Center, Port Washington, N.Y., "Television As a Means of Mass Instruction in the Armed Forces."

TUESDAY AFTERNOON

R. L. Garman and R. W. Lee, General Precision Laboratory, Inc., Pleasantville, N.Y., "Television Pick-Up Tubes and Techniques Used in Studio Film Chain Cameras."

Richard S. O'Brien, Columbia Broadcasting System, Inc., New York, N.Y., "CBS Television Staging and Lighting Practices."

D. C. G. Hare, D. C. G. Hare Co., New Canaan, Conn., and W. D. Fling, Fairchild Recording Equipment Co., Whitestone, N.Y., "Picture-Synchronous Magnetic Tape Recording."

J. S. Hall, A. Mayer and G. Maslach, General Precision Laboratory, Inc., Pleasantville, N.Y., "16-Mm Rapid Film Processor."

R. L. Garman and Blair Foulds, General Precision Laboratory, Inc., Pleasantville, N.Y., "Some Commercial Aspects of A New 16-Mm Intermediate Film Television System."

Wayne R. Johnson, Earle C. Anthony, Inc., KFI-TV, Los Angeles, Calif., "Progress Report on An Experimental Electronic Background Projector for Television."

Rudy Bretz, Dramatic Workshop and Technical Institute, New York, N.Y., "Television Special Effects."

TUESDAY EVENING

Carl Meyers and F. R. McNicol, WGN-TV, Chicago, Ill., hosts for a conducted tour of WGN-TV's new studios in process of completion.

Ted Lawrence, CBS-TV, New York, N.Y., Chairman for a discussion period on television studio lighting, with brief discussions by: Carl Meyers, F. R. McNicol and George Petterson, WGN-TV; and Frank Koerner, WENR-TV, Chicago, Ill.

Oscar Holmes, Holmes Projector Co., Chicago, Ill., Demonstration of New Direct Film and Background Projector.

WEDNESDAY MORNING

M. Sultanoff, Terminal Ballistic Laboratory, Aberdeen Proving Ground, Md., "A 100,000,000 Frame Per Second Camera."

Elinor Porter Muhl, Earl H. Hinz and C. A. Main, Department of Aeronautical Engineering, University of Minnesota, Minneapolis, Minn., "High Speed Photography of Reflection—Lighted Objects in Transonic Wind Tunnel Testing."

C. D. Miller, Battelle Memorial Institute, Columbus, Ohio, "Phenomena Involved in Engine Knock Photographed at 40,000 to 200,000 Frames Per Second."

WEDNESDAY AFTERNOON

Brian O'Brien, Gordon G. Milne and William Covell, Institute of Optics, University of Rochester, Rochester, N.Y., "High Speed Image Dissection Camera Type II."

H. N. Olsen and W. S. Huxford, Department of Physics, Northwestern University, Evanston, Ill., "Electrical and Radiation Characteristics of Flash Lamps."

Frederick E. Barstow, Edgerton, Germeshausen and Grier, Inc., Boston, Mass., "Infra-Red Photography with Electric Flash."

Paul M. Fye, Naval Ordnance Laboratory, White Oak, Md., "The High-Speed Photography of Underwater Explosions."

John Nash Ott, Jr., John Ott Pictures, Inc., Winnetka, Ill., "Time Lapse Motion Picture Photography."

THURSDAY AFTERNOON

H. J. Benham, Brenkert Light Projection Co., Detroit, Mich., and R. H. Heacock, RCA Victor Division, Camden, N.J., "A New Deluxe 35-Mm Motion Picture Projector Mechanism."

Arthur J. Hatch, The Strong Electric Corp., Toledo, Ohio, "The Differential Carbon Feed System for Projection Arc Lamps."

Herbert Griffin, International Projector Corp., Bloomfield, N.J., "A New Heavy Duty Professional Theater Projector."

Henry J. Hood, Eastman Kodak, Co., Rochester, N.Y., "Report of SMPTE 16-Mm and 8-Mm Motion Picture Committee."

J. W. McNair, American Standards Association, New York, N.Y., "Standardization on Photography and Cinematography."

Tom H. Miller, Training, Dept., Eastman Kodak Co., Rochester, N.Y., "Stop and Go Signs in Color Photography."

THURSDAY EVENING

W. W. Lozier, National Carbon, Fostoria, Ohio, "Report of SMPTE Screen Brightness Committee."

Herman H. Duerr, Ansco, Binghamton, N.Y., "Report of SMPTE Color Committee."

W. T. Hanson, Jr., Research Laboratory, Eastman Kodak Co., Rochester, N.Y., "A Color Negative and A Color Positive Film for Motion Picture Use."

Edgar Gretener, Edgar Gretener, A. G., Zurich, Switzerland, "Physical Principles, Design and Performance of the Ventarc High-Intensity Projection Lamps."

FRIDAY MORNING

M. G. Townsley, Bell & Howell Co., Chicago, Ill., and P. L. Pryor, Air Materiel Command, Wright Field, Dayton, Ohio, "A Large T-Stop Calibrating Unit."

E. E. Strauss, J. G. Zuber and M. G. Townsley, Bell & Howell Co., Chicago, Ill. "A New Portable 35-Mm Motion Picture Camera."

William P. Bielicke, George W. Colburn Laboratory, Chicago, Ill., "Conditions and Progress in the German Motion Picture Industry."

H. Goldin, Gaumont-Kalee, Ltd., Toronto, Canada, "The Acoustic Design of New Odoen Theatres."

May Benson, MacKay Research Laboratory, Chicago, Ill., "Photo-Sensitive Devices and Excitation Sources."

George W. Colburn, George W. Colburn Laboratory, Chicago, Ill., "Double and Single Film 16-Mm Projectors with Variable Picture/Sound Synchronization for Laboratory and TV Studio Use."

FRIDAY AFTERNOON

John G. Stott, Du Art Film Laboratories, New York, N.Y., "Report of SMPTE Laboratory Practice Committee."

E. K. Carver, Eastman Kodak Co., Rochester, N.Y., "Report of SMPTE Film Dimensions Committee."

H. W. Cleveland, Research Laboratory, Eastman Kodak Co., Rochester, N.Y., "A Method of Measuring Electrification of Motion Picture Film Applied to Cleaning Methods."

Thomas T. Hill, The Edwal Laboratories, Inc., Ringwood, Ill., "Securing Optimum Results in Fixing and Washing Photographic Materials."

R. Paul Ireland, EDL Co., Chicago, Ill., "A Method of Tone Reproduction Control in Reversal Processing."

C. A. Horton, Research Laboratory, Eastman Kodak Co., Rochester, N.Y., "Printer Control in Color Printing."

John P. Kiel, Producers Service Company, Burbank, Calif., "A 35-Mm Process Camera."

Don Norwood, Pasadena, Calif., "Light Measurement for Exposure Control."

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